ANALYTIC

PHYSIOLOGY.

By SAMUEL HOOD, M. D. A. B.

"KNOWLEDGE IS POWER."—*Bacon.*

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MDCCCXXII.

TO

GEORGE CHARLES, M.D.

EDINBURGH.

My Dear Sir,

I hesitate not for a moment to inscribe this work to you, under whose bold, enlightened, and successful practice I first acquired a desire to investigate the causes and treatment of disease. I rejoice to avail myself of this occasion to express the high esteem which I entertain for your worth, and my lasting gratitude for the obligations which I have derived from your interest and friendship.

I have the honour to be

Your obedient humble servant,

S. HOOD.

PREFACE.

FOR the last six years, I have been collecting facts which bear forcibly upon the general principles of Physiology; and I have at different times arranged them in various shapes, for the purpose of laying them before the public in some periodical publication; but I found they embraced so many parts of Physiology, that it was impossible to bring them into any reasonable compass, without a brevity which would render them at once obscure, entangled, and unconnected. For this reason, I prevented the publication of a paper which was submitted to the Royal Society in 1819, and which contained some of the facts related in the following work. Thought is the essence of science, and is most easily conveyed from a

judicious arrangement of materials. To apply properly the new facts dispersed in the following work, I have been under the necessity of taking rather an extended view of the Animal Economy; but as there is no separate work on Irritability, in the Medical Literature of this country, I felt impressed with the idea, that such a publication, if tolerably well executed, would eventually be acceptable.

At present, there are no Medical authorities more highly esteemed than Haller and Bichat; and if I had written merely for a local or transitory popularity, it would probably have been more judicious to make a compilation of their works, than to controvert their opinions. But literature invariably decays, when the authority of authors preponderates over the authority of Nature. "In the same manner," if I may use the words of Longinus, "as children always remain pigmies, whose infant limbs have been too closely confined; thus our tender minds, fettered by a just servitude, are unable to expand themselves, or attain that well proportioned greatness which we admire in the ancients." Such, in some

degree, is the thraldom in which the Medical profession is held by Haller and Bichat; but neither the learning of the former, nor the eloquence of the latter, will permanently maintain the popularity of opinions which are false in themselves, and destitute of every practical result. The great error of these celebrated writers on Irritability, consists in their apparently mistaking expansion of the fibrous texture in general, for mechanical elasticity; and contraction, under all circumstances, for a state of increased action. When John Hunter speaks of muscular contraction, from the "stimulus of death," he uses language quite consonant with Haller and Bichat, but certainly at discord with Nature.

In their account of Irritability, the action of the nervous system is set almost out of the question, while it is the principal agent concerned in all the motions of the fibres, whether voluntary or involuntary. The cause of Irritability I have, in imitation of Gaubius, called the Vital Force, a term which is also used by

Chaussier. In this country, the Vital Force is usually called the Nervous Power, an epithet which is faulty, because it leads to the belief that it is generated exclusively by the Nervous System.

Arguing from facts, is commonly called reasoning, but in Medicine it frequently receives the appellation of theory; and as I have given the reasons by which I arrived at new facts, I shall, in every probability, be stigmatized as a theorist. This charge I shall make no attempt to extenuate. I have related facts, with all the accuracy of which I am capable; and pointed out, as far as I have been able, the causes from which they spring, and the laws by which they operate, without either disrespect or servile deference for any authority past or present.

Not many of the theories which I have advocated are entirely my own; some crude vestiges of most of them may be found in the records of Medicine; and so far at least I ought to escape the odium of innovation.

Being more anxious to secure the judgment than catch the fancy of my readers, I have bestowed little decoration on the style, which has been sacrificed for the purpose of arraying truth in its simplest garb. There are other defects for which I ought, perhaps, to apologize; the difficulty of the subject claims some allowance, and Wisdom is rarely, like its presiding goddess, mature from its origin.

At first it was my intention to have included the Irritability of the Glands; but finding that the completion of this plan would have considerably enlarged the work, without adding much to its value, I thought it advisable to conclude with Visceral Irritability.

In general I have mentioned those authors to whom I have been indebted for any particularly important idea, and observed as much as possible respect for literary property, individual as well as national. The writings of Sir Everard Home, Dr. Davy, and Mr. Brodie, have afforded me both facts and examples for deviating from the

Physiology of the Schools; and indeed it is but justice to Sir E. Home, to confess that this volume originated from his work on Strictures.

To Dr. Sillar, of the Liverpool Dispensary, I am particularly indebted for his assistance in collecting facts, for which I return him my most grateful and hearty thanks.

LIVERPOOL,
June, 1822.

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ERRATA.

Page 34, line 12, for " strong" read " strong as"

41, 1, for " $\frac{a}{\eta}$" read " $\frac{2}{\eta}$"

42, 2, after " same" insert " time"

102, 23, for " ansarca" read " anasarca"

104, 26, for " obnoxoius" read " obnoxious"

120, 27, for " corpera" read " corpora"

125, 19, for " asphixia" read " Asphyxia"

ANALYTIC PHYSIOLOGY.

SECTION I.

The Vital Force.

1. THE vital force is a power generated in all parts of the body, between the nerves and blood-vessels; it is the primary agent in all the operations which take place in the animal economy; it is peculiarly modified in every organ, and diversified by disease and moral affections.

11. The simplest effect of the vital force is the generation of heat, which affords a pretty accurate gauge of its intensity, and with which I shall commence, according to the analytic method that I have adopted in the following work. As irritability, with the exception of voluntary muscular contraction, is regulated by the intensity of the vital force, it naturally follows to be considered after animal heat. In this manner, the irritability of all the organs will be separately treated, as well as their relation to the rest of the body and to each other.

III. A question naturally presents itself in limine, viz. What is the Vital Force? To give even a brief outline of the various opinions which have been propounded respecting it, would far exceed the bounds of this work; and the late publication of the learned and scientific Dr. Barclay renders it even unnecessary. One opinion, however, which has, with some variations, prevailed more or less from the remotest antiquity, merits at least cursory consideration, both from the appearance of truth which it has lately assumed, and the celebrity of those who have held it.

IV. The sophis of the East entertained a notion, that the Deity is diffused throughout all matter, and that the whole of animated nature is only varied manifestations of the Divinity; and hence arose their wild and indiscriminate polytheism. The highest material form assumed by the Deity they regarded to be man, whom they supposed to be re-united to the Eternal Mind at death. This doctrine was introduced into Greece by Pythagoras, under the name of Anima Mundi, or Soul of the World, afterwards so renowned in Greek philosophy.

V. Newton adopted the opinion of Pythagoras and the sophis, but with some alterations and additions. All nature he conceived to be pervaded by an extremely subtile ether, which is not only the cause of attraction in matter, but

even of the phenomena of life in organized bodies. This ether, or electricity, he abundantly proved to be an essential property of all matter. Franklin discovered it to be a compound substance.

VI. In the mean time, animal electricity was not wholly overlooked. The faculty which the torpedo and the gymnotus electricus possess, of numbing those who assail them, had long embellished the fire-side tale of the mariner; but Redi, physician to the Grand Duke of Tuscany, was the first to show that this faculty is in proportion to the liveliness of the animal. In 1772, Mr. Walsh established, by a series of experiments, the identity of the numbing power of the torpedo and electricity. To this valuable information, Mr. Hunter added an accurate description of its galvanic apparatus. In 1816, Mr. Todd, of the navy, communicated even a more important physiological fact to the Royal Society of London. He divided the nerves of the torpedo which go to be distributed in its galvanic battery, and found that, in consequence, it lost entirely the power of giving electric shocks. Mr. Todd's experiments were varied sufficiently to demonstrate, that the torpedo's power of generating galvanic electricity depends essentially on the nerves.

VII. Many other inductive reasons corroborate the identity of electricity, galvanism, magnetism, and the vital force, an opinion which has of late

years received the support of several physiologists of great repute. But supposing their identity completely established, which I conceive is the case; physiological research is not therefore to remain stationary. Our knowledge even of galvanism is confined to a few of its properties, its nature being quite unknown; nor, indeed, is the knowledge of first causes absolutely requisite for practical utility. The chemist estimates the specific gravity of an elementary body, describes its colour, and determines its combinations with other substances, without pretending to comprehend its ultimate particles. The mathematician also calculates the force with which attraction operates on bodies at various distances, without holding himself bound to say what attraction is. Ought not the physiologist to follow a similar principle in the investigation of the animal functions, and leave the nature of the vital force in the same uncertainty as the chemist does the atoms of an element, and the mathematician attraction? This is the view of the vital force which I propose to take; but I shall, nevertheless, point out, as I proceed, its analogies to galvanic electricity.

SECTION II.

Animal Heat.

I. THE faculty of generating a constant supply of caloric, is a property peculiar to living organized bodies; some have also alleged its existence even in vegetable life, during the spring and summer. Animal heat is too remarkable a phenomenon to have escaped the scrutinizing spirit of the Greeks: they distinguished two sources of it in the animal economy, the εμφυτον θερμον, or innate heat, and the συμφυτον θερμον, or connate heat. The connate heat they conceived to be a portion of the semen, or blood of the mother, forming the substance of all our organs, and belonging to the hot and dry elements. The innate heat they thought to be a nobler substance than the elements, being of a divine nature, and having its seat in the heart. This theory of animal heat prevailed to the time of Willis, who affirmed, that the heart communicates even incandescent particles *(scintillas)* to the blood in its passage through the ventricles.

II. Towards the close of the 17th century, the pneumatic theory of animal heat began to obtain

converts, among whom was the celebrated Stahl, who supported it with all the weight of his authority, both as a professor and an author. It was not founded, like the preceding theory, on simple assertion, but had enough of reasoning in its support to give it a scientific appearance. Birds, said its advocates, respire a great quantity of air, and have a high animal temperature; fishes and reptiles respire little, and possess a low temperature; while in man the heat augments with increased rapidity of the respiration, and *vice versa*. On these slender premises was founded the opinion, that animal heat is caused by respiration. The pneumatic theory met with few opponents; it adapted itself with facility to the humoral pathology of the time; neither did it militate against the doctrine of autocrateia, for which Stahl and his followers were determined sticklers. On the discovery of oxygen, by Priestley and Lavoisier, there existed no disposition on their part to limit its influence; the former having shown, that it is the grand agent of combustion in general; and the product of respiration and combustion being the same, the probability therefore was, that an evolution of caloric takes place in the lungs during respiration.

III. Boerhaave had observed, that the agitation of atmospheric air with venal blood, changed its colour from a deep purple to a bright scarlet tint.

This fact successively occupied the attention of Hales and Cigna. Priestley repeated their experiments, and examined the air, after having agitated it with blood, and found it to be the same as respired air; or, in other words, the oxygen of the atmospheric air had been changed into carbonic acid gas. It was previously well known, that the blood undergoes a remarkable change, from a purple to a scarlet colour, in its passage from the pulmonary arteries to the veins; and the changes which take place in the properties of the blood and air being apparently the same in respiration, as when the blood and air are agitated together in a bottle, the inference, that respiration is the source of animal heat, was almost unavoidable. One formidable objection was still to be overcome, the temperature of the lungs was not found to differ from that of the other cavities.

IV. The important chemical fact observed and illustrated by Black, that bodies, at the same temperature, contain unequal quantities of caloric, was ingeniously applied by Dr. Crawford, to explain away the objection in question. He undertook a series of experiments for the purpose of showing, that the difference of capacity for caloric, in venal and arterial blood, and in atmospheric air and carbonic acid gas, might account for the absence of augmentation of free caloric in the lungs, and explain, at the same

time, the generation of animal heat by respiration. Thus, according to him, atmospheric air contains a much greater quantity of specific caloric than carbonic acid gas; and the oxygen of the atmospheric air taken into the lungs being changed into carbonic acid, a disengagement of caloric equal to the difference of their capacity for it, should happen during every inspiration. But the capacity of arterial blood for caloric being 1.0300, and that of venal only .8928; the heat generated by the formation of carbonic acid in the lungs, he supposed to be absorbed in a latent state, by the arterial blood which again disengaged it, in a free state, in its transition through the capillary vessels.

v. The opinions of Priestley and Crawford were no sooner published in England, than Lavoisier and the Marquess La Place undertook the investigation of the same subject. They placed guinea-pigs in a calorimeter, and kept them in it for several hours; they then estimated the quantity of ice melted, and of carbonic acid formed, during their stay in the calorimeter. They afterwards formed an equal quantity of carbonic acid by combustion in the calorimeter, and found that nearly the same quantity of ice had been melted by the guinea-pigs while they remained in the calorimeter, as by the process of combustion in the last experiment.

vi. The pneumatic theory of animal heat was thus apparently proved analytically and syntheti-

cally. Few physiologists were able to resist its chemical plausibility; and with the exception of Mr. Hunter, it was almost universally credited in the United Kingdom, and publicly taught in the universities.

VII. The truth or fallacy of this theory may be considered in two points of view: did Dr. Crawford deduce his conclusions from accurate premises? and doth it explain the numerous remarkable morbid variations of temperature in nervous and inflammatory diseases? A sufficient body of facts, accumulated within these last twelve years, warrants an answer in the negative to both questions.

VIII. Respecting the capacity of carbonic acid for caloric, Dr. Crawford fell into a grievous error. The latest experiments on the capacity of gases for caloric, are those of Berard, Delaroche, and Mollet, which seem to have been executed with great exactness. Taking the capacity of atmospheric air for caloric at 1.0000, they make that of carbonic acid 1.2583, while Crawford estimates it at 1.0454, atmospheric air being 1.7900. Concerning the difference of venous and arterial blood, Dr. Crawford was wrong likewise in his statement, though not as widely as in the gases. From a number of experiments on this subject, published in the Philosophical Transactions of 1814, Dr. Davy has shown, that "there is no

material difference between venous and arterial blood, in respect to specific caloric, excepting what arises from difference of specific gravity." Dr. Crawford erred also in supposing, that an estimate of the caloric produced by chemical combinations can be made from the capacity of the new production. Professor Dulong of Paris, has lately observed, that in the chemical combination of two bodies, a vast quantity of caloric may be disengaged, and the capacity of the resulting compound remain about the mean capacity of the two ingredients. Dr. Crawford's calculation of the quantity of caloric generated during inspiration, is therefore altogether conjectural; his conclusions, consequently, are unworthy of implicit credit. It may further be objected to the pneumatic theory of animal heat, that supposing it to be caused by respiration, the degree of heat ought always to correspond with the quantity of air respired; whereas an individual may respire during* digestion one-fourth greater quantity of oxygen than before a meal, and the animal temperature not vary one degree.

IX. Forcible as these objections may appear against the pneumatic theory, Mr. Brodie has the honour of having effected the most conclusive refutation of it: he divided the spinal marrow of a rabbit, tied its carotid arteries, and fixed a pair

* Vide Lavoisier and Seguin.

of bellows to the trachea, by which means he carried on its respiration and circulation for an hour and a half; a thermometer placed in the thorax, stood at 86°. Another rabbit, of the same size and colour, had its circulation stopped by the application of a ligature to the base of the heart; and at the end of an hour and a half, the heat of its thorax was 88½°. Mr. Brodie repeated these experiments frequently, from which he draws the general conclusion, that "when the air respired is colder than the natural temperature of the animal, the effect of respiration is not to generate, but diminish animal heat." If physiology, like the other sciences, is to be founded on facts, it is impossible to dissent from Mr. Brodie's conclusion: the pneumatic theory must therefore necessarily be abandoned, and recurrence made to the antiquated doctrine of Hippocrates, Philiston, and Diocles, who regarded respiration as a ventilation of the innate heat.

x. The mathematical physiologists alleged, that the motion of the blood is a source of animal heat; but this notion is contested by Mr. Hunter, than whom there is no more powerful advocate for the influence of the blood in general. "Animal heat (says this distinguished author) does not depend on the motion of the blood; the nose of the dog, which is always nearly of the same heat in all temperatures of the air, is well supplied

with blood." Again, speaking of a man afflicted with apoplexy, he adds, "while he lay insensible in the bed, covered with blankets, I found that his whole body would in an instant become extremely cold in every part, continuing so for some time; while these changes were going on alternately, there was no sensible alteration in the pulse for several hours." This is a strongly marked case, but it is impossible to attend a large hospital long, without observing cases resembling it to a certain extent; at one time, the heat is greatest at the temples, the cheeks, or the region of the liver; at another, the diminution of temperature extends over half the body. The following is the most important case of this kind that has ever come under my own observation, and which I shall detail with accuracy, as it bears not less strongly on the subject of irritability, than that of animal heat:—

XI. January 1820. M. Deschamps, aged 49 years, had an attack of apoplexy, in February 1819, which terminated in hemiplegia of the right side. The fingers of the right hand are now firmly clinched, and require a very considerable force to open them; the pupil of the right eye is much dilated; the pulse of the paralytic arm is stronger and fuller than that of the sound one: the temperature of the room being 9° of Reaumur, the heat of the paralytic hand is 19°, and the healthy

one at 22°. Whether this anomaly in the circulation of the two arms had arisen from some organical difference in the structure of their arteries, or from the treatment which he had received, it is difficult to decide; perhaps both these causes might have co-operated, for he had taken nux vomica in great quantities; and in all the cases of paralysis where this medicine had been administered, I have uniformly found the pulse of the paralytic arm comparatively strong. Two small eschars, made with the nitrate of silver, were formed on the head; at the end of two weeks there was no perceptible effect from them, except that the right iris had expanded nearly to its natural dimension. The temperature of the room, and the superior extremities, being nearly in the same relation as above stated, an eschar, the size of a sixpence, was made on the back of the neck, but causing no alteration of temperature, another, half the size, was formed on the head. The day following, there was little alteration of the pulsation; but the temperature of the paralytic hand was found to have risen from 19° to 22° Reaumur; the heat of the whole hand had also risen something more than $\frac{1}{4}$th of a degree. The flexor muscles of the right hand, which had formerly been in a state of rigid contraction, were now expanded, and easily moved by external force; but voluntary motion was not in the least restored.

When the sloughs fell off, the iris alone remained permanently affected by the eschars; the muscles of the paralytic arm fell back to their former contracted state, and its temperature to its usual low standard, when exposed to a cold atmosphere. The eschars were consequently discontinued. When this patient was in bed, and well-covered with blankets, the heat of the paralytic muscles was natural. This circumstance, so far as my observation extends, is common to all cases of hemiplegia.

XII. In patients afflicted with hemiplegia, the circulation is in general languid on the whole of the paralytic side; but even in all such cases it is easy to raise its temperature to an equality with that of the whole side, by a lunar caustic eschar, if the apoplectic symptoms have for some time disappeared. A case of this description I shall relate under the head of Muscular Irritability. As an eschar of lunar caustic, over the nerve of a paralytic limb, causes an augmentation of heat through all its ramifications, it necessarily follows, that the nervous system must contribute greatly to the generation of animal heat; but as the nervous system may be made to cease its calorific action, by the abstraction of blood, animal heat must therefore be a product arising from the combined action of the blood and nervous system, and does not depend solely upon either the one or the other.

In paralytic extremities it would, however, appear, that the nerves require a stronger excitement than that of the blood, to produce the natural disengagement of caloric whenever the patient is exposed to a cold and free atmosphere; but in health the motion of the blood, its contact with the nervous system, and the friction of the muscles, are adequate to support the calorific process requisite in the animal economy.

XIII. Intense thought, not long continued, creates increased temperature of the head; when the mental functions are suspended by sleep, the temperature generally sinks about one degree. Whatever operates powerfully on the nervous system, such as violent pain, fear, grief, and miasma, causes a reduction of animal temperature; cold may be so intense as to suspend or destroy this and all the other functions of the nerves.

XIV. Some have supposed, and among others Mr. Hunter, that the human body possesses a frigorific as well as a calorific power; this is physically impossible, for two properties, incompatible with each other, cannot exist in one body at the same time. The following is one of the experiments on which Mr. Hunter lays great stress: "the living and dead parts (two penes) being both immersed in water, gradually made warmer and warmer from 100° to 118°, and

continued in that heat for some minutes, the dead parts raised the thermometer to 114°, while the living raised it no higher than 102¼°." The venous blood of the living penis must necessarily have carried off a considerable quantity of caloric, as all the blood which passed through it, during the immersion, would acquire the temperature of that organ. If the circulation of the blood had been stopped, there is no valid reason to suppose, that the living penis would not have been of the same temperature with the dead one.

XV. An atmosphere, heated considerably above the temperature of the blood, communicates its caloric but slowly to the human body. Sir Joseph Banks and Dr. Fordyce remained (without having their heat much augmented) fifteen minutes in a humid atmosphere at 130°; but if the stay in a heated atmosphere be protracted, the animal heat may be raised five or six degrees, as hath been proved by Messrs. Berard and Laroche.

XVI. Although 98° of Fahrenheit is regarded generally as the healthy natural temperature in Britain, yet in some individuals it is lower than this in the winter season; and "every temperature of the air above 62°, applied to the human body, is found to increase the heat of it." In tropical countries, when the temperature of the atmosphere in the shade rises to 90°, the heat of the blood

rises to 100°. Animal heat being subject to such variations, cannot be said, with accuracy, to have a fixed natural standard.

XVII. Infants born before the expiration of nine months from the time of conception, frequently die, owing to the inability of their nervous system to support caloricity.

XVIII. The blood being the grand exciter of the nervous system, any considerable determination of it to one part, necessarily occasions a local or general augmentation of caloric. If the afflux of blood to a part be local, as in phlegmon, the increased heat is also local; if it be to the brain, and the other viscera, as in agues, the temperature of the whole body is augmented; but if the cold fit of an ague be prevented by a lunar caustic eschar on the spine, the hot fit does not ensue. The blood may, however, be accumulated in one part to such a degree as to entirely annihilate its vitality; thus, severe inflammation often terminates in gangrene; and violent determination to the cavities, in spasm, coma, and death.

XIX. It has been argued, and with every appearance of truth, that the decomposition and reproduction of solids and fluids, which is ever going forward in all living organized matter, should contribute to the generation of caloric. It is indeed true, that most chemical combinations

are attended by some change of temperature; it is therefore in unison with fair induction to infer, that decomposition is a source of animal heat.—But chemical combinations in the human body are themselves the consequences of the vital force.

XX. It is impossible to completely destroy the vital force in an instant, by any violence, however severe. The bodies of those who die suddenly of apoplexy, or who are suffocated by gases, cool down to the common temperature of surrounding objects much slower than the corpses of those who die of lingering, or even acute, diseases. This difference in the cooling of dead bodies, can arise only from the generation of heat, after the cessation of breathing and pulsation.

XXI. The quantity of caloric constantly escaping from the human body, is immense. An ordinary-sized man is calculated to inspire 100 cubic feet of air in twenty-four hours; and if its temperature be 32°, it is raised to about 96° by the animal heat communicated to it during the act of respiration. About two pounds of water, in a state of vapour, pass off by pulmonary exhalation in twenty-four hours, which must absorb 900° of caloric in assuming an aëriform state. The insensible perspiration also abstracts no inconsiderable quantity of caloric.

XXII. Some animal heat likewise goes off by radiation; but from the comparative facility with

which coloured surfaces part with their caloric, this circumstance is most remarkable in negroes, whose skin usually feels cold to the touch of a white person.

XXIII. In tropical countries, the temperature of the atmosphere being often equal to that of the human body, no caloric can, in such circumstances, be taken off by the air respired; but the absence of this cooling process is counterpoised by the vast increase of cuticular evaporation, which is supported by a comparative diminution of the aqueous part of the urine.

XXIV. From these chemical sources of cold, and from the human body being an indifferent conductor of caloric, it can for a short time resist, without injury, the influence of an atmosphere heated to 212°, and even upwards according to some statements.

XXV. As the blood necessarily acquires the temperature of the organs through which it circulates, it loses part of its caloric in the capillaries of the extremities. Dr. Davy states the difference of heat, in arterial and venous blood, to be one degree, thermometers being placed in both ventricles of the heart. There is no valid proof, however, that this difference is owing to respiration.

XXVI. After the relation of all the above facts, it appears superfluous to insist on the necessary

conclusion, that animal heat is caused by the mutual action of the nervous system and the blood. It is generated wherever there are nerves and blood-vessels; and when reduced locally or generally by disease, it may be raised artificially to its natural height, or even beyond it, without the slightest inflammation. But all this being admitted, it still remains to determine what is the substance thus produced. Avoiding probability and conjecture as the Scylla and Charybdis of physiology, I shall simply state the analogies of galvanic electricity, and the vital force so far as it has been examined.

XXVII. The quantity of caloric generated by galvanism, does not correspond with the bulk of the metallic elements employed to excite it, but depends on multiplying their points of contact; neither does the degree of animal heat correspond with the quantity of its exciting substances, but depends on multiplying their points of contact.

XXVIII. Diluted nitric acid is the most effectual means of augmenting the caloric of a galvanic trough. Combined with the oxide of silver, or diluted with water, it is also the most effectual means of augmenting animal heat when externally applied.

XXIX. These analogies between galvanic electricity and the calorific process of living organized matter, can hardly be fortuitous coincidences;

but it is better for the physiologist to remain in philosophic doubt, than to believe conclusions founded upon ambiguous or insufficient data, while others equally plain and definite may be advanced. In these times it is fashionable roundly to condemn generalization in science; but it is difficult to take an enlarged view of the phenomena of nature without rencountering multifarious affinities in her operations, and to generalize from facts is as correct and demonstrative, as it is puerile and absurd to generalize from bare or syllogistical assertion.

SECTION III.

Irritability.

xxx. By irritability is here understood the expansion and contraction of the soft fibrous structure of the human body. Haller, in opposition to Glisson and Gorter, confined its signification to muscular contraction. But irritability, in the extended sense of the word, comprehends the motions of the skin, muscles, viscera, glands, and vascular system. The subject of irritability has been not a little obscured by the method in which it has been usually investigated: to kill an animal, and apply chemical agents to its nerves and muscles, and to employ the consequences of these applications to the explanation of vitality, must lead to false conclusions. The muscles are thus subjected to an influence different from the vital force, and different consequences arise from it.

xxxi. In the view of irritability which I am about to offer, I shall, for the most part, consider all the organs in which it is situated, in their entire state, and under the influence of the vital

force; by which means I hope to explain some of the important functions of the animal economy, and arrive at a few conclusions of practical utility.

XXXII. To avoid also any obscurity from artificial technical classification, I shall distinguish the varieties of irritability by the anatomical denomination of the organs in which it exists. This arrangement is convenient in some respects, for though the vital force be the agent of motion in organized bodies, yet each organ is constructed to move by peculiar stimulants which only modify its vital force: light augments the action of the optic nerve, but is without influence on the olfactory and auditory nerves.

SECTION IV.

Dermoid Irritability.

XXXIII. Since Malpighi, anatomists have divided the dermoid system into scarf-skin, rete mucosum, and true skin; but the existence of the rete mucosum in the skin of Europeans has recently been questioned. The various tints of the human skin are derived from the rete mucosum, which are modified by the double influence of climate and temperature.

XXXIV. In the course of five or six generations, Europeans, settled in tropical climates, assume the colour of the aborigenes: the descendants of the Portuguese, who first visited the East Indies by sea, are now as dark as the Hindoos. But though tropical countries darken the European skin, yet a temperate climate does not turn a black skin white. The Diemenese, who enjoy an excellent climate, in south latitude 43°, are as black as the negroes of Calabar and Biafra.

XXXV. The skin is a spongy substance, of different thickness in various parts of the body; it is amply supplied with nerves and blood-vessels, and perforated in all parts by the exhalants and

lymphatics. The pores of the skin are extremely numerous, Leewenhoeck reckoned 12,000 in a square inch; they are largest on the nose and back, where they are quite visible to the eye.

XXXVI. The whole of the dermoid system expands and contracts; but in some parts the irritability is greater than in others. This exception being made, wherever the animal heat is greatest, there also the expansion of the skin is most considerable. This rule is equally applicable whether the augmentation of heat be local, as in phlegmon, or general, as in common continued fever.

XXXVII. Expansion of the skin, and animal heat, do not, however, stand in the mutual relation of cause and effect; they both result from the vital force; but the degree of expansion may in general be estimated with tolerable accuracy by the degree of animal temperature.

XXXVIII. The part of the skin which possesses the greatest irritability, is unquestionably the scrotum: diminish its vitality by the application of cold, and it instantly corrugates itself; restore its natural degree of vital force by an increase of temperature, and how speedily it again expands!

XXXIX. While the animal heat ranges between 97° and 101°, the skin permits the free egress of the sweat through the extremities of the exhalants; but when it rises above this, the expansion

of the skin becomes sufficient to close, in a greater or less degree, the orifices of the exhalants, and obstructs the sensible perspiration. If a person labouring under continued fever (whose animal heat is at 105°, and skin tense and dry) be bled to syncope, the skin contracts by the reduction of the vital force, the aqueous particles of the blood ooze from the exhalants, and its whole surface is speedily covered with large drops of sweat. I use this illustration of dermoid irritability, because it is a familiar fact, and daily presents itself to the observer.

XL. Europeans, on their first entering the tropics, are extremely liable to suffer from too great expansion of the skin, from which arise pustules, prickly heat, and frequently continued fever. The skin is best kept from expanding too much, by taking a proper quantity of liquids; the evaporation from the surface of the body prevents the vital force from being morbidly increased.

XLI. The Lady Castlereagh transport, crowded with troops, passed in a few days from a latitude where the temperature of the atmosphere was at 36° to one at 90°. The allowance of water to each man, was only five pints a day. Two or three new cases were daily added to the sick list, which increased to an alarming degree. Another pint of water was added to the former allowance, and not another new case of fever occurred

during the remainder of the voyage, which lasted two months.

XLII. The fever which arises from scarcity of water, follows the general course of Cullen's synochus, except, that so far as I have been able to ascertain, it never commences with cold shiverings or vomiting.

XLIII. In tropical climates, when the skin is dry, and the temperature of the body at 100°, it is astonishing with what rapidity profuse perspiration follows a draught of water.

XLIV. The skin on the paralytic side of a person afflicted with hemiplegia, is also paralyzed, and consequently opposes no obstacle to the egress of the sweat; but the same deficiency of vital force which diminishes the expansion of the skin, reduces also the expansion of the exhalants, and prevents the fluids from reaching the skin in usual abundance. There are, however, some cases of hemiplegia, where the sweating is profuse on the paralyzed side, while the other remains quite dry. Bichat mentions one case of this kind, and Dr. Sillar recently had the goodness to show me a patient affected in a similar manner.

XLV. The pores of the skin permit only the most aqueous parts of the fluids to pass through them, while it is in a healthy state. But in continued fever, when the skin loses its expansibility so far as to permit the exit of a

thick, viscous exudation, commonly called a clammy sweat, just apprehension may be entertained of approaching dissolution; but in the nervous diseases of Europe, this symptom may be often observed without any dangerous consequence.

XLVI. Were it not for the expansion of the skin, the serum of the blood would run off, by the exhalants, as in the sudor anglicanus; when the extreme vessels become morbidly expanded, the skin becomes so also, by which means exudation of the fluids is rendered impossible.

XLVII. Exanthematous diseases being excepted, the skin reaches its maximum of expansion in bilious fever, and its maximum of contraction in the sudor anglicanus, paralysis, and those cases of continued fever which terminate in clammy sweats.

XLVIII. The hot bath, by the excitement which it gives to the vital force at the surface of the body, can produce very considerable expansion of the skin; on those parts where it is thickest, such as the soles of the feet and the palms of the hands, a long continuance in the hot bath causes such an expansion, that it appears puckered and too large for the parts which it covers.

XLIX. The sweat is apt to condense in the pores of the skin, and make it appear unctuous and spotted, and exhale a disagreeable odour. Besides the detergent property of the hot bath, the

expansion of the skin which takes place during immersion, is by far the most effectual method of expelling the condensed perspiration from the cutaneous exhalants, and preserving the pliability, health, and beauty of the dermoid system.

L. The sweat is chiefly composed of water and acetous acid, but like other secretions its composition is very changeable.

LI. Physiologists have laboured hard to establish the quantity of perspiration by the skin; Keil reckons the mean quantity for this country at thirty ounces in twenty-four hours. But in tropical countries it cannot fall much short of five pounds, from the quantity of liquids requisite to preserve health.

LII. Strong mental affections, especially those of a disagreeable nature, often alter the irritability of the skin in a very short time. Dr. Alibert relates the case of a man who was attacked on the spot where he stood, with herpes, from seeing his master dragged to the scaffold by the revolutionary mob. I extract the following case of tinea asbestina from the same author: "This woman experienced the most bitter affliction, owing to the ill treatment which she received from her husband and children. When she was a little tranquil, the parts affected furnished an abundant suppuration, the crusts fell off, and the tinea seemed healing. When, on the contrary,

her vexation was great, the crusts were dry, and pains of the head severe."

LIII. As the skins of the negroes are generally at a lower temperature than those of Europeans, they are consequently more difficult to expand; and owing to this property of their teguments, they are less liable to fevers than Europeans in tropical regions.

LIV. I forbear speaking of the properties of the skin after death, from a belief that they do not accord with those which it possesses during life.

SECTION V.

Muscular Irritability.

LV. According to the opinion of Haller, irritability is an innate, peculiar, inherent property of muscular fibres; while he, at the same time, admits the influence which the vital force and volition exercise upon them. The doctrine having had most extensive credit with physiologists, I shall insert the author's own words: "Seperavi quidem irritabilem naturam hinc a vi mortua, inde a vi nervosa, et ab animæ potestate." Whether there be a foundation in nature for these nice distinctions of Haller, I am not to decide; but I shall confine myself chiefly to the consideration of the general effects produced on the muscles by variations of the vital force, both in health and disease.

LVI. *Expansibility of Muscles.*—Moderate expansion is the natural quiescent state of the muscles; it is quite involuntary; or, at least, is effected without any effort of the mind, except when opposing muscles are employed to extend their antagonists with more speed, or to a greater than

ordinary extent. Though the hand be firmly closed, a constant effort of the will is required to maintain it in that state, and prevent the natural expansion of the flexor muscles of the fingers and wrist. But if the muscles be retained long in one position, as practised by the Fakirs of Hindostan, they lose their expansibility by continued inaction.

LVII. The expansibility of the muscles does not depend on their physical elasticity; for if it did, expansion would take place with mechanical velocity to a given extent, and ought to exist after death.

LVIII. In all diseases which cause high augmentation of the animal heat, muscular expansion undergoes a corresponding increase; hence may, in part, be explained the difficulty with which muscular contraction is performed in febrile complaints.

LIX. The case of Deschamps, already given in the article on Animal Heat, (XI.) is an incontrovertible proof that muscular expansibility depends on the vital force; but I shall offer a still more conclusive example to the reader's consideration.

LX. April 6th, 1819.—Hugh Ward, private dragoon of the army of Bengal, aged thirty-six years, joined a detachment of the 25th cavalry, on board the Mangles transport, at Madras, bound

for England. He was affected with hemiplegia of the right side. His arm was shrunk and deprived of all voluntary motion; the flexor muscles of the fingers and the extensor longus pollicis were contracted, the fingers were in consequence closed, and the thumb drawn radiad; the leg and thigh were shrivelled, but he could walk a little. His disease had commenced by a stroke of apoplexy, three months previous, during which period he had remained in the Garrison Hospital of Madras, where he had been repeatedly bled and blistered.

LXI. April 11th.—An eschar was made in the right axilla with the nitrate of silver. On the following morning, when questioned respecting the effect of the eschar, he replied, "Shortly after the issue was made, I felt my hand open." This being the first paralytic patient that I had treated with lunar caustic, I was not a little surprised to see him move his fingers, wrist, and fore-arm with facility. The pulsation of the radial artery was become much stronger; and a thermometer placed in either hand stood at 100°, the temperature of the atmosphere between decks being 90°.

LXII. It became shortly after evident, that in future, it would be necessary to make the eschar over the cervical vertebræ, for the muscles of the shoulder joint, notwithstanding the intimate con-

nection of its nerves with the axillary plexus, continued quite motionless.

LXIII. April 25th.—A new eschar was made over the third cervical vertebra, with the view of influencing the nervous action of both extremities by one application. The effect was nearly as remarkable as that of the first eschar; for, two hours after its application, he could move the humerus (which till now had been motionless) backwards and forwards, or hold it at a right angle with his body. The pulsation was not so strong when the eschar was in the axilla, but the temperature of the hand was still at 100°. In order to exercise his muscles, he was directed to lift weights and increase them as he acquired strength; in six weeks, the eschar being renewed at intervals of ten or twelve days, he could carry sixty pounds, and write his own name.

LXIV. The cure was thus advancing slowly and successfully, but it did not keep pace with my wishes; the eschar was renewed on the back of the neck, and a fresh one made over the first lumbar vertebra. Instantly after the second application, the right arm felt numb, and the patient could not close his hand, owing, apparently, to the excessive expansion of the muscles; the pulse was strong, head-ache troublesome, and the animal heat increased. In the course of two days, he took three doses of antimonial wine;

all the disagreeable symptoms disappeared, and the cure went on as usual.

XLV. After the sloughs fell off, I tried to carry on the cure by frictions with the liniment of ammonia, but the arm remained quite stationary; cold affusions of water on the paralytic side, and preparations of cinchona had no better effect. After losing a whole month in these fruitless expedients, I resumed the application of eschars. The remainder of this case is too tedious to relate here; it is enough to state, that before the patient disembarked at Greenwich, October 21st, he could carry two hundred pounds' weight, and walk pretty well, considering that he had had so little opportunity of exercising his limbs.

XLVI. The circumstance to which I would particularly draw the attention of the reader in this case, is the expansion of the flexor muscles of the wrist and fingers after the first eschar; the involuntary opening of the hand was the first effect from the augmentation of the vital force by the lunar caustic, which was too obvious to escape even the patient's observation.

LXVII. The expansibility of paralytic muscles is not confined to those cases in which voluntary muscular motion can be restored; besides the case of Deschamps, which is illustrative of this, I have seen two others exactly of the same, one

in my own practice, and the other in Dr Sillar's. When an eschar does not permanently restore the expansibility of the muscles, it begins to diminish on the fourth day, and they arrive at their usual morbid state of contraction about the eight or ninth.

LXVIII. The expansion caused by the vital force must not be confounded with expansion caused by external force, or the contraction of opposing muscles.

SECTION VI.

Contractibility of Muscles.

LXIX. The vital force has hitherto been considered as a simple substance, arising from the combined operation of the nerves and blood-vessels, as a power generating heat, and expanding the muscular fibres. These preliminary propositions being established, what is the cause of muscular contractibility? The muscles themselves being the production of the vital force, it must, I conceive, necessarily follow, that they derive their faculty of contracting from the same source. Taking this for granted, it remains to be shown, what are the modifications of the vital force which cause the opposite states of muscular expansion and contraction. The subject may be taken in two points of view; the first is the opinion of Hoffman, who seems to have considered morbid muscular contraction as simply caused by reduction of the vital force; the latter is to regard the vital force as a compound substance. Hoffman's theory is the most useful one that has ever been advanced, but it is not appli-

cable to voluntary contraction; or, in other words, voluntary contraction contradicts the hypothesis, for it is inconsistent to suppose that debility, or a diminution of the vital force, can be the cause of voluntary contraction. On this principle, also, contraction ought to be strongest after death, when the vital action has ceased.

LXX. The theory of Hoffman has found few followers of much reputation; Cullen, indeed, gave it a sort of qualified support, but his strong mind was probably fettered by the Haŭerian doctrine of irritability. Although I shall, in imitation of my predecessors, for the most part, treat the vital force as a simple substance, and follow generally the theory of Hoffman, I beg leave to offer a few arguments for thinking it a compound body.

LXXI. No simple substance can, by itself, generate caloric; but wherever there is a developement of heat, two or more substances combine to produce it. Animal heat is a production of vitality, which is probably generated by the combination of two sorts of vital force, which neutralize each other like positive and negative electricity.

LXXII. Berselius has proved, as I conceive, that to effect the decomposition of any body, the co-operation of positive and negative electricity is absolutely necessary. From the impregnation of

the ovum to the last expiration, incessant decomposition is going forward in the human body. The vital force is the cause of decomposition in the animal economy; vitality must, therefore, on this principle, be a compound substance like electricity.

LXXIII. It was reasoning upon this principle, that induced Dr. Sillar and myself to put pieces of meat into a wound made in a dog's thigh, and to try if the vital force would decompose them. The success of the experiments is a strong presumption in favour of the reasoning which pre-supposed the results which were afterwards obtained on trial, and which will be related in the section on digestion.

LXXIV. Muscular contraction not being the mere absence of expansion, is also another proof that there must be a negative contractile, as well as a positive expansive vital force.

LXXV. A theory of irritability, formed on the compound nature of vitality, would refer expansion of the whole fibrous structure of the body to the positive vital force, and contraction of the same to the negative vital force which is communicated to the voluntary muscles by the mind, and to the vascular system and intestinal canal, by their contents. If this theory do not afford a clue to voluntary contraction of the muscles, I know not what will: it has at least the merit of several

facts in its favour. But, after all, voluntary motion is one of those links in the inexplicable chain which unites soul and body in this world, and which belongs, perhaps, more properly to psychology, and is probably more a subject of curiosity than utility: I shall therefore not dwell upon it, but proceed to morbid contraction, which is more within the reach of human capacity.

SECTION VII.

Morbid Muscular Contraction.

Σπασμὸς γινετο ἢ Πληρώσιος ἢ κενωσιος.—HIPPOCRATES.

LXXVI. Morbid muscular contraction has been divided by medical authors into tonic and clonic spasm; Cullen has employed the word Spasm in place of Tonic Spasm, and Convulsion instead of Clonic Spasm. I shall follow, generally, this distinction of the learned Professor, although I do not consider spasm and convulsion as essentially different.

LXXVII. Morbid contraction is caused by reducement of the vital force. Direct diminution of the vital force may be effected by hemorrhage, senescence, cold, fear, and planetary influence; and indirect diminution by congestion of blood, or other chemical, mechanical, and mental stimulants.

LXXVIII. When life is terminated by old age, the flexor muscles, as they become deprived of their vital force, contract, and draw the limbs and

body into a state of flexion; the extensors, deprived of their vital force, contract at the same, but are overcome by the physical power of the flexors; the body thus coils itself up, as it were, when the vital force is gradually extinguished. Moses, in his description of the patriarch Jacob's death, has paid particular attention to this state of the body at the extinction of vitality: "And when Jacob had made an end of commanding his sons, he gathered up his feet into the bed, and gave up the ghost, and was gathered unto his fathers." This is a brief and accurate history of dying, and describes that coiling of the body which precedes dissolution.

LXXIX. Indirect diminution of the vital force, causing morbid contraction, may be exemplified by hemiplegia. A very considerable quantity of blood is required to keep the nervous system in a sufficient degree of healthy excitement; but if it collect in too great abundance in the brain, or spinal marrow, convulsions and paralysis are the consequence. On this subject there can be only one opinion, viz. that congestion of blood is the cause of hemiplegia, and prevents the generation of a proper quantity of vital force.

LXXX. The followers of Haller readily admit that paralysis is caused by diminution of the vital force; but spasm and convulsion, according to them, proceed from an augmentation of it. "The

vital force," says Bichat, " manifests itself in two opposite states: in paralysis, and convulsions; the first is the sign of diminished energy, and the second of augmented energy."

LXXXI. It is no uncommon circumstance to see a limb convulsed and paralyzed at the same instant; in such a case, is it either logical or comprehensible to assert, that the paralyzed limb hath its vital force both augmented and diminished at the same moment? Convulsions, also, invariably follow profuse hemorrhage, which is, notwithstanding, the most effectual means that can be employed to reduce the vital force when it is too high.

LXXXII. The keen observation and discerning judgment of Bichat, could not have permitted him to fall into such a palpable mistake, had his ideas not been entangled in the Hallerian irritability. But to the opinions of Bichat and Haller, may be opposed those of Hoffman: " quo vehementior itaque spasmus est, et quo diutius partem affligit; eo major atonia, imbecilitas ac virium resolutio relinquuntur."

LXXXIII. If augmentation of the vital force be the cause of convulsion, then ought the muscles to be convulsed by inflammation; but, unless there be, at the same time, a cerebral congestion, they are, in all diseases of an inflammatory nature,

the furthest removed from spasm, being for the most part nearly at their maximum of expansion.

LXXXIV. The spasm and convulsion which occur in the cold stage of febrile diseases, are of little moment, as the re-action which follows, usually restores the expansibility of the muscles. But convulsions appearing after an acute disease has lasted a considerable time, should awaken the liveliest apprehension of the practitioner: they indicate a high degree of danger, and are, indeed, most commonly, the precursors of death.

LXXXV. It being possible to refer all morbid muscular contraction to direct or indirect reduction of the vital force, I shall investigate it under these two kinds of causes, which, though apparently different, produce effects essentially the same.

LXXXVI. *Spasm of stricture.*—The simplest form of spasm from direct reduction of the vital force, appears to be stricture of the urethra. Exposure to severe cold, causes first spasm of the urethra and stoppage of urine, the penis becomes small and hard; the cremaster muscles next contract, and afterwards the muscles of the abdomen and inferior extremities. These symptoms are attended by a great reduction of animal temperature, and the cold stage of an ague-fit is formed. But whenever the re-action of the nervous system has raised the animal heat, the

expansibility of the urethra and muscles is also restored. In stricture there is no miasma or contagion to distract the attention; the cold simply reduces the vital force, the urethra contracts, and remains so, till it is expanded by re-action.

LXXXVII. On the other hand, the injudicious use of bougies and caustics may occasion spasm and ague, which follow the same course, as in the first instance. The spasm and the ague are the same in both the above cases; only, that in the first, the vital force is directly diminished by the sedative power of cold; and indirectly in the second, by excitement carried so far as to diminish for a time the function of the pudic nerves.

LXXXVIII. In a physiological point of view, the spasms of stricture are of remarkable importance, as the hot stage of the ague removes the spasms, and restores the mobility of the muscles; a circumstance rarely observable in any other spasmodic disease in Europe.

LXXXIX. *Spasm of Indian cholera.*—This disease is endemial in the East Indies, from the Indus to Japan. In the various dialects of British India, it has been called Modexim, Nicobea, Sheni, Viduma, Visuchi, and Woba; in Sagar's Nosology, it is named cholera Indica. Although I conceive that Cullen has, with great propriety, restricted the genus cholera, to a purging and vomiting of bile, yet I shall follow the nomenclature of Sagar,

and call this disease Indian cholera. To this appellation, however, I would be understood to attach no value whatever, as the disease is altogether sui generis.

XC. The Indian cholera being annually endemial on the Coromandel coast, is well known to the Hindoos, and is treated of at considerable length in their sacred writings. In the first wars of the English in the Deccan, it was very destructive among the native troops, and even fifty Europeans fell victims to it; a frightful loss, when it is recollected, that the armies of Lawrence and Clive seldom contained a thousand men.

XCI. The Indian cholera prevailed epidemically in Mysore and Arcot during 1780 and 1782. In 1818, during the war against the Raja of Nagpore, it pervaded every division and battalion of the British army; in three days, one European regiment lost no less than 330 soldiers and camp-followers. When it assumes its most epidemic form, it suspends, for a time, the ordinary business of life; and sometimes, even arrests the progress of military movements; passengers attacked by it in the street, drop down, and often expire on the spot where they are taken ill.

XCII. The Indian cholera is the same as the epidemic spasm of Bontius; and Kempfer observed a disease among the Japanese, which bears a close resemblance to it in many respects.

XCIII. The following case shows all the three stages of this disease, with a feeble re-action between the two last.

XCIV. Sergeant Stromberg, aged 30, had a slight diarrhœa during the night. I saw him at six o'clock in the morning, and thinking his complaint of a trifling nature, I ordered him a small dose of rhubarb; he had, in the course of the day, two or three liquid stools, but at eight in the evening the disease assumed the character of Indian cholera. He did not, however, send for assistance till ten o'clock, by which time, he had vomited an enormous quantity of whey-coloured fluid; the animal heat was very low, and the pulse weak; the muscles of the abdomen were corrugated into large knots by incessant spasm; the muscles of the legs and arms were also in a spasmodic state; and the pain which he suffered was excruciating. He was ordered fifty drops of laudanum, in some brandy and water; he had also a scruple of calomel, but the whole was rejected in a few minutes. The calomel was repeated, and again rejected in a quarter of an hour. A blister was then applied to the epigastric region, and bottles, filled with hot water, to the feet. His thirst was excessive, and he urgently demanded acids and cold water, to drink. Although the animal temperature seemed reduced nearly to the level of surrounding objects, he

complained bitterly of heat, and made constant efforts to throw off the warm blankets which were heaped upon him. Between twelve and one o'clock, I could no longer feel the pulsations at the wrist, but they were perceived by Mr. Forster, surgeon of the 46th regiment. It is impossible to convey in words, an accurate idea of his looks, but they were expressive of anguish and despair; or, to use the words of Bontius on a similar occasion, "nos truculenter intuebatur." About three o'clock, the symptoms began to moderate, and the pulse rose, but the re-action was very weak. During the following day, he took two grains of calomel every two hours, and had occasional vomitings and liquid stools. He continued getting better till next morning at eight o'clock, when he was seized with delirium, and convulsions of the whole body, and died in fifteen minutes, the disease having lasted altogether about fifty-eight hours.

XCV. The dissection of this patient was extremely satisfactory. When the upper part of the scull was removed, the brain seemed to rise up, as if the cavity of the cranium had been too small for it. Between the pia mater, and tunica arachnoidea, there was a considerable quantity of serum. The blood-vessels of the brain were excessively distended, but there was no effusion in the ventricle. The blood-vessels of the lungs and abdominal viscera, were rather turgid, but neither

the internal coat of the stomach, nor duodenum, exhibited the minute injected red appearance of inflammation. The gall-bladder was filled with bile, resembling half liquid pitch.

XCVI. In numerous instances, the patient dies comatose, without any re-action, which always terminates the disease, when it is sufficiently brisk to raise the animal temperature a little higher than natural.

XCVII. Private Charles Williams, whom I had previously known for several years, had one liquid stool at three o'clock in the morning, and when returning to his bed, he felt a few wandering spasms in his legs, which went off in a minute or two. At ten o'clock, the spasms of the legs and abdomen became instantly very severe; when I reached his bed-side, his face was so pale and altered, that I with difficulty believed it possible, that his features could have been changed in such a manner as to make him appear at first an unknown individual. The pulse was 80, and very feeble; the gastrocnemii muscles were contracted, and hard to the touch, like a piece of wood; he was holding them with both hands, and screaming with pain. At this time he had no vomiting, but I was certain that it would soon come on, when I heard that he had been purged in the night. He was ordered a strong dose of laudanum, in

brandy and water; and was carried to the hospital of Fort St. George, where he arrived before the vomiting began, which happened soon after. Mr. Forster, the surgeon of the 46th regiment, ordered him to be put immediately into the warm bath, which seemed to relax the muscles for some time, but when he was taken out, the spasms returned with renewed violence. Sinapisms were now applied to the abdomen and legs. At twelve o'clock, the sinapisms began to give pain, and the muscles to relax; he had taken a pint of strong brandy punch, which he retained half an hour, and had been purged only once. At three o'clock P.M. the sinapisms giving great pain, were taken off; the pulse was 90, and strong, the features natural, and the spasms had nearly ceased. Not having seen the patient at this hour, I cannot mention the state of the animal heat; but, from the strength of the pulse being restored, it may be presumed to have been higher than natural. The artificial re-action thus excited, prevented compression of the brain, and effusions in its ventricles or meninges, by restoring a due proportion of the fluids to the extremities and surface of the body. The day following, he made no complaint whatever, excepting the pain of the abdomen and legs, where the sinapisms had been applied the day previous; the disease had, in fact, terminated in the artificial re-action.

XCVIII. These two cases show the general course of the Indian cholera, whether it terminates in re-action, or the comatose stage. The Indian practitioner ought carefully to discriminate these different stages of this disease, lest he should confound it with other complaints of a milder nature.

XCIX. *The first or purging state.* The patient is troubled with occasional watery stools, and slight griping pains of the abdominal viscera; these symptoms are usually so moderate, that the patient is not in the least apprehensive of his critical situation. The duration of this stage is very uncertain; sometimes it precedes the cold stage two or three days, and at other times only a few hours.

C. So far as my own observation goes, there is no possibility of distinguishing these symptoms from a common looseness; but, if the Indian cholera be epidemic at the time, every purging ought to be instantly stopped, and narrowly watched.

CI. *The second or cold stage.* The first symptoms of this stage are paleness of the face, feebleness of the pulse, and great reduction of the animal temperature; the spasms of the abdominal viscera become gradually more violent, the muscles of the abdomen and extremities contract into hard lumps, and cause intolerable pain.

CII. All these symptoms may be present for some time, without purging or vomiting, but most commonly they are excessively violent. The fluid evacuated, both upwards and downwards, resembles in some degree the serum of the blood mingled with the contents of the alimentary canal. It is of a wheyey colour, or like water in which raw beef has been washed.

CIII. The thirst is excessive, and the patient calls instinctively for acids and cold water. Sometimes the muscles of the lower jaw contract to such a degree as to form a real trismus; sometimes the head is drawn violently towards the knees, and the heels towards the breech.

CIV. The arms seem less subject to spasm than the sacral extremities, but they always suffer more or less from it. The skin becomes clammy; the countenance wild, staring and haggard; the pulse is feeble, or imperceptible; and the patient complains of heat, although his temperature be greatly reduced. This stage lasts from one to seven hours.

CV. *The third or apoplectic stage.* When the cold stage is long and violent, the blood accumulates in all the cavities, the brain becomes gradually compressed, and the intellectual faculties are either temporarily suspended, or life itself is terminated in a coma.

CVI. The apoplectic stage may terminate favourably in a brisk artificial re-action, often in death, and sometimes, though rarely, in hemiplegia or hydrocephalus.

CVII. The excessive pain of the spasms may, I apprehend, be regarded as one of the causes of death, or the coma which precedes it.

CVIII. When a weak re-action succeeds a long cold stage, as in Stromberg's case, the patient recovers his intellectual faculties for some time, but relapses sooner or later into apoplexy.

CIX. The Hindoos frequently die of this disease in one or two hours, and even Europeans have fallen victims to its severity in four or five from the commencement of the cold stage.

CX. In the above description, I have regarded the purging which precedes the violent symptoms of the disease, as an essential part of it, as I have never seen one case in which there had not been one or more liquid stools before the invasion of the cold stage. The patient is, however, often unable to give any thing like an accurate account of his previous state, till after his recovery; little reliance can therefore be placed on any thing which he may utter while writhing with the agonies of the cold stage.

CXI. Dissection shows the blood-vessels of the brain and its membranes to be always greatly distended before death; serous effusions are also

commonly to be found in the ventricles of the brain, on its surface, or between its membranes. The gall-bladder is most commonly filled with black viscid bile.

CXII. As death constantly occurs by coma following the cold stage, the blood-vessels of all the viscera are found immoderately full; this sort of mechanical distention is regarded by many practitioners as inflammation of all these organs.

CXIII. The physiological question at issue in this place, is the cause of spasm in Indian cholera.

CXIV. When this disease is epidemic, it prevails at all seasons of the year; in the Deccan it is endemial only in the rainy season, and attacks chiefly those Hindoos who are badly clothed and indifferently nourished. The Mahomedans of the same country are little subject to it, from their using a more nutritive diet.

CXV. Accustomed to go nearly naked, in an atmosphere that is generally about 90° in the shade during the day, the Hindoos have the blood-vessels at the surface of the body preternaturally distended; but during the prevalence of the north winds on the Coromandel coast, when the atmosphere is moist and cold, contraction of the extreme vessels causes a great determination of the fluids to the viscera, if the effects of the season be not counteracted by clothing, and nourishing aliment.

CXVI. Upon the same principle, the colour of the Indian's skin must contribute to the above change in the distribution of the blood, as black surfaces radiate caloric faster than white ones.

CXVII. Persons under salivation, whether for dysentery or lues venerea, are obnoxious to the Indian cholera; and notwithstanding the high repute of calomel as an antidote against it, there are strong reasons for suspecting that salivation may be reckoned among its exciting causes.

CXVIII. The cholera morbus of Cullen, was prevailing among the newly-arrived troops in Fort St. George, while the Indian cholera was prevalent there in 1818, but in no instance did the latter terminate in the former. One officer had no less than three relapses of common cholera, which never showed the slightest tendency to assume any of the characteristic symptoms of the prevailing epidemic.

CXIX. Those persons who are properly clothed and use a nutritive diet, with a moderate quantity of wine, are almost secure against this disease, even in its most epidemic form. The 25th dragoons, stationed in —— at Arcot, were 500 strong; nearly 100 privates took the Indian cholera, but not one officer had it.

CXX. Some entertain the belief, that this disorder is contagious, but from its extreme brevity

this is very improbable; it is no uncommon circumstance to see a patient who had been at the verge of existence in the morning, able to follow his ordinary business before evening.

CXXI. I have seen Europeans and Asiatics exposed, in every sort of manner, to the effluvia of those afflicted with this malady; but in no instance were any of these individuals ever attacked by it, although fatigue, anxiety, and want of rest, predisposed their constitutions to be readily affected by any specific contagion.

CXXII. It is rather a curious circumstance, that this complaint should be most prevalent at the lunation, of which Mr. Horton, of the 34th regiment, has adduced several proofs.

CXXIII. At present, the most popular opinion respecting the Indian cholera, seems to be, that it is of an inflammatory nature. This notion is either true or false, according to what is understood by inflammation. If every preternatural afflux of blood to an organ constitute inflammation of it, then the Indian cholera is an inflammation of the brain, lungs, and abdominal viscera. But, on the other hand, if inflammation consists in the augmentation of the animal heat, increased expansion of the extreme arteries, pain, and preternaturally strong pulsation in a particular organ, then the Indian cholera is the farthest removed from inflammation of any disease known.

CXXIV. Whatever increases the animal temperature, also increases every inflammatory disease, but cures the Indian cholera: inflammation is aggravated by accelerating the circulation; the Indian cholera is relieved by it.

CXXV. The blood-vessels of all the viscera, are, indeed, fuller than natural, after the first stage; but the lower the animal heat is, and the weaker the pulse, the more violent are the spasms; no sooner does the motion of the blood become more rapid, and the animal heat natural, than the symptoms invariably vanish. "Si febris adsit, cor ac arterias refrigerat benigne." Bontius.

CXXVI. I shall not, here, enter into any altercation with those who contend that spasm is caused by increased action of the nerves; but I appeal to the daily experience of every unprejudiced physician, whether he considers the vital force high or low when the pulse is imperceptible at the wrist, and the animal heat no higher than the surrounding atmosphere; it requires little physiological discernment to know, that if both heat and circulation be not restored, death must inevitably follow. Such is very frequently the state of a patient in the third stage of Indian cholera; and if the spasm that attends it arise from an increase of nervous action, we may reasonably ask, when is it diminished?

CXXVII. But the vital force is, in fact, diminished directly, from the beginning of the disease, which rarely attacks those in whom it is supported by the proper necessaries of life. In the last stage, the vital force may also be indirectly diminished by the collection of the blood in all the cavities, which more particularly affects the brain, and impedes its functions.

CXXVIII. A natural re-action, sufficiently strong to restore the expansibility of the muscles, seldom occurs in the cholera of India. The celebrated Italian missionary, Batholomeo, who had great opportunities of observing it, never saw one patient recover without the aid of some stimulant, and all those "who refused assistance, died in two or three hours." Mr. Deville, a French surgeon, presented a paper to the Academy of Paris, in 1820, where he says, that he had seen this disease terminate favourably in a natural re-action; but this circumstance must be very rare.

CXXIX. In every disease but this, when the blood is concentrated in the cavities, re-action always restores the balance of the circulation, unless there exist, at the same time, lesions of the viscera; but three obstacles oppose re-action in the cholera of India. In the second stage, the serum of the blood escapes profusely by the intestinal exhalants, and the spasm of the muscles

compresses the nerves of the extremities. In the third stage, the surcharge of blood, by which the brain is overwhelmed, induces coma and death.

CXXX. Artificial re-action may be effected by the internal use of alcoholic liquors, and the external application of sinapisms, the spirituous vapour bath, and cauterization with diluted nitric acid, as recommended by Mr. Powell, assistant surgeon in the Bombay army. The coma of the third may also be averted by timely recourse to blood-letting.

CXXXI. The above physiological fact may be briefly summed up under the following heads:—

CXXXII. 1. Till the commencement of the second stage of Indian cholera, there is only a slight determination of the fluids to the alimentary canal.

CXXXIII. 2. The vital force being very low in the second stage, there is consequently a great reduction of the animal temperature, and the expansibility of the muscles, skin, and extreme vessels; while the blood accumulates in all the cavities, and its serum oozes from the intestinal exhalants.

CXXXIV. 3. In the apoplectic stage, the mental functions become suspended by excessive pain, and a superabundance of blood, from which proceed compressed brain and effusions of serum.

CXXXV. 4. When a brisk re-action is timely excited, the disease terminates in it, except a trifling diarrhœa, which sometimes remains a day or two after the other symptoms.

CXXXVI. Should the English ever have to dispute the throne of Timour with European enemies, the Indian cholera would probably become a subject of vast political importance to the invaders, as well as the invaded. In three or four days, it may cause more havock in an army than a pitched battle. The destiny of a campaign of this description, would depend almost as much on the judgment and decision of the medical staff, as on the *materiel* of the armaments, and the valour and discipline of the troops.

CXXXVII. *Spasm of Tetanus.*—The causes of tetanus which directly reduce the vital force, are, excessive fatigue and exposure to a cold moist atmosphere, after violent exercise, or any thing which augments the animal temperature. Sometimes it appears spontaneously, or at least without any very obvious exciting cause. Trismus nacentium is confined almost exclusively to cold countries.

CXXXVIII. The causes of tetanus which indirectly reduce the vital force, are, wounds, lacerations, or indeed any external lesion; which are, however, usually attended with some local excitement.

Tetanus caused by injuries of this sort, is called traumatic tetanus; when confined to the muscles of the lower jaw, trismus.

CXXXIX. The vital force is known to be diminished in tetanic spasms, by the lowness of the animal temperature, and by the paralysis of the pharyngeal muscles, which occurs towards its termination. Tetanic spasms are symptomatic in the cholera of India, and sometimes even in hemiplegia; in the latter of these diseases, they are always caused by an afflux of blood to the head. In health, the muscles are pliable, and easily yield to any moving power applied to them; but even in the intervals of tetanic spasm, they resist external force, and every attempt at motion (whether voluntary or not) is apt to throw them into involuntary contraction.

CXL. The contractile force of the muscles is prodigiously increased in tetanic spasm; in the cold stage of Indian cholera, the patient sometimes takes hold of pieces of furniture, and tears them asunder with more than Herculean strength.

CXLI. At first sight it appears inconsistent to say, that the causes which excite spasm, and double or treble the contractile power of the muscles, should operate by reducing the vital force; but this difficulty is explained away, by

recollecting that their expansibility is also an effect of vitality, and not of mechanical elasticity.

CXLII. Sir James Macgrigor states, that tetanus arises from every description of wounds, and at every period of their cure. If a wound be suppurating at the time when the spasms commence, the discharge becomes serous and scanty; but when they disappear, the suppuration resumes its healthy properties; this circumstance induced Baron Larrey to employ means to restore the suppuration, which he alleges to have sometimes cured the spasms.

CXLIII. A slight scratch or puncture on any part of the body, seems very inadequate to throw the muscles into tetanic spasm; but if the subject be examined by severe induction, it will be seen to correspond in a great measure with the general laws of sympathy between the different remote parts of the nervous system. From the intimate connexion of all the nerves with each other, many local affections have a tendency to operate upon organs situated at a distance from the diseased part; thus slight incised wounds sometimes bring on syncope, not from loss of blood, but from sympathy of the brain with the injured part; and convulsion of the muscles of expiration in sneezing, is an example of the same kind. That convulsion and coma, and even para-

lysis, proceed often from the presence of worms in the alimentary canal, is familiar to every one, all which morbid symptoms can be occasioned only by the influence which one part of the nervous system has upon another. Upon like principles, a general spasm of the muscular system from a trifling hurt, is easily conceivable, and quite agreeable to the analogies of sympathy.

CXLIV. Tetanus, whether arising from local injuries or exposure to cold, may be termed a local disease; for till towards its termination, the functions of the brain and pectoral viscera are unimpaired, and even digestion and secretion are little deranged. So soon as the muscles of inspiration participate in the spasm, death is necessarily near at hand.

CXLV. Although the vital force be reduced in all spasmodic diseases, there are modifications of its reducement in them, as there are varieties of its excitement in febrile disorders; but in what these differences consist, it is probably in vain to seek after.

CXLVI. The pain of tetanic spasm is excessive, and arises apparently from the pressure of the muscles upon the nerves which run through them. In the course of life, almost every body has cramp of the gastrocnemii muscles, which is attended with excruciating pain; but the instant that the

opposing muscles mechanically overcome the spasm, the pain is removed. To this opinion it may be objected, that tetanus in one instance caused no pain; but a few anomalous cases can neither establish nor overthrow general physiological principles. In the spasm which sometimes attends hemiplegia, the pain is indeed usually inconsiderable, or wears off; but in cases of this description, the sensibility is at the same time impaired. And most authors agree, that the persons most obnoxious to tetanus, are those who have very strong, rigid muscles, and are about the prime of life.

CXLVII. The propagation of spasm from muscle to muscle, in stricture and tetanus, would seem to favour the inference, that the pressure of the muscles upon the nerves operates like ligatures, and that the spasm of one muscle becomes the cause of spasm in those adjacent to it.

CXLVIII. I entirely coincide with Aretæus, that tetanus is a disease of the nerves, but others hold different opinions. From worms having been often detected in the bowels of persons who had died of tetanus, some have considered these vermin as the cause of the disease. Since anatomists have carried their search of disease into the vertebral canal, a more plausible doctrine, founded upon the morbid appearance of the spinal marrow,

has been advanced by Broussais and others, who allege that it is caused by inflammation.

CXLIX. If the spinal marrow within the cervical vertibræ is always inflamed or surrounded with serum in tetanus, it follows that this morbid appearance must be either a cause or consequence of the disease. The serous membranes are doubtlessly very liable to inflammation and effusions, which may aggravate the spasm of tetanus, when they occur in the neurilema of the spinal marrow; but the absence of inflammation in one instance, overturns the theory of its being the cause of tetanic spasm. Such a case I have been informed has been found, but not having seen it, I shall lay little stress upon it. Serous effusions are found in abundance in the cholera of India, but they are invariably the consequences, and not the causes of spasm. To the serous effusions in spasm, Bontius called the attention of physicians a hundred and twenty years ago, but till of late this subject has been unaccountably neglected.

CL. If tetanus be an idiopathic inflammatory disease, how comes it that the blood is more liquid than natural, and that the animal heat is not raised? How comes it, that, when a patient suffering from tetanus is attacked by fever, the spasms are dispelled? Hippocrates was the first who observed this fact, which has not, however, had that weight with physicians which it deserves,

although it is corroborated by analogy and some high modern authorities. The following is the observation of Hippocrates to which I allude, and so far as it applies to tetanus, I have full confidence in its truth:

Ὑπὸ σπασμὸν ἢ τετανάνε ενοχλεμένω, πυρετος επιξενομενος λυει το νοσμημα.—Aphoris. lvii. Lect. iv.

Although this aphorism contains a rather too extended conclusion, as applied to convulsive diseases in general, yet most of them are occasionally terminated favourably by fever.

CLI. Excepting the local treatment recommended by Baron Larrey, when the spasm is referable to external injury, the present practice in tetanus is empiricism in the most extended sense of the word. Like other obstinate disorders, tetanus has a superfluity of antidotes, which seldom succeed but in the hands of their proposers: in recommending any new treatment, discrimination between spontaneous and artificial cures is rigidly required.

CLII. The Arabian physicians, observing the general absence of re-action in tetanus, recommended the excitement of an artificial fever, but knew not how to effect it. Their proposal may or may not be successfully practised, but it is in perfect harmony with the aphorism of Hippocrates above quoted, who was little apprehensive of fever or inflammation in nervous diseases.

CLIII. It has been shown that re-action seldom occurs in the cholera of India, owing to the too great afflux of blood to the viscera; in tetanus it also rarely happens, because there is little or no determination to the cavities.

CLIV. *Convulsion* is distinguished from spasm by the muscles being agitated by alternate contraction and expansion without the concurrence of volition. Convulsion may be either general, as in epilepsy, or local, as in asthma, or the *tic* of the French authors. Convulsion may be symptomatic in all diseases which terminate in death, but the observations which I have to offer, will be confined chiefly to idiopathic convulsive disorders.

CLV. *Epileptic convulsions.* — Aretæus calls epilepsy a disease of the brain, as one of the characteristic distinctions between it and tetanus. All the causes of epilepsy may very properly be classed after Cullen's method, into sedative and stimulant causes. This disease is sometimes hereditary; more commonly it arises from some severe shock received by the brain, which is at one time of a physical, and at another of a moral nature.

CLVI. As epilepsy may be defined to be a suspension of the mental functions of the brain, together with a reducement of its vital force, it is not therefore to be inferred, that the brain is in a state of excitement during an epileptic fit, although it may have been brought on by a

stimulant cause, which only augments the energy of the brain previous to the accession of the fit. The causes which operate in this manner are mechanical, chemical, and mental stimulants, and plethora of the cerebral blood-vessels. As the operation of some of these causes is often rather obscure, I shall relate a case arising from plethora, which will nevertheless serve to illustrate the general action of stimulants which produce epilepsy.

CLVII. John Briton, of Boston, aged thirty years, received a wound on the head, in an affair of boats during the last American war. Excepting four epileptic fits, which he had in the course of as many years, he enjoyed good health in his own country; but on his arrival at Calcutta in 1818, the fits became frequent, and lasted usually about four hours. At the accession of the fit there was always a decided determination of blood to the head, the face being red and the pulse full; but as the fit advanced, the face became gradually paler, the pulse irregular and weaker, and respiration extremely imperfect. While the blood-vessels contained comparatively a moderate quantity of blood, he remained free from fits: two copious bleedings were commonly required to effect the necessary depletion of the brain, which prevented the epileptic accessions for five or six weeks: about the expiration of this period, the

plethora and the disease always returned. During six months that he was under my care, I became so well acquainted with his constitution, that I could foretel within a day or two the return of his disease.

CLVIII. In the above case, two stimulating causes contributed to bring on the disease, viz. plethora of the cerebral vessels, and increased temperature: mechanical stimulus no doubt was the first cause of the disease, but no more influence could be ascribed to the injury at Calcutta than in America.

CLIX. When epilepsy is caused by stimulants, the pulse is usually fuller than natural for some time before the fit, but towards the conclusion it becomes extremely languid.

CLX. There is not a more popular, nor a more palpable error in medicine, than the belief that, because the vital force is augmented by several stimulants, their effect must be the same, whatever may be the degree of intensity with which they are applied to the nervous system. Cullen has fallen into this error, by dividing epilepsy into collapse and excitement of the brain. When the disease arises from a stimulating cause, there is not a doubt that the energy of the brain is ordinarily increased before the fit; but when this has commenced, circumstances are quite altered. The mental functions of the brain are so far from being increased, that they are completely inter-

rupted; the vital force is not increased, because there is no augmentation of animal heat, and the soft fibrous texture does not possess its natural expansibility; even the intestinal canal, which is less under the cerebral influence than the muscles, sometimes contracts to such a degree that the feces are expelled during the convulsive paroxysm.

CLXI. Lastly, epilepsy terminates occasionally in apoplexy, which is any thing but an excitement of the brain, although it is unquestionably caused by stimulants. Upon the whole, it would therefore appear, that those who regard epilepsy, under any circumstance, as an excitement of the brain, confound cause and effect.

CLXII. Those causes of epilepsy which directly diminish the vital force, are hemorrhagy and depressing passions, as grief, fear, and horror; to these perhaps may be added the aura epileptica, on which, however, I have no distinct notion. Cullen alleges that several poisons also directly reduce the energy of the brain.

CLXIII. When epilepsy has occurred once, it always leaves behind a predisposition to relapse. At the battle of Leipsic, a French conscript was standing near the sergeant-major of his corps, when a cannon ball struck the latter on the head, and besprinkled the former with the brains of his companion. The young soldier was so shocked at the accident, that he fell instantly into an epileptic

fit, which returned habitually about once a month. In this case, the vital and mental functions of the brain were directly reduced by a scene abundantly horrific to a mind not yet hardened with warfare.

CLXIV. In epilepsy arising from emotions of the mind, we have no clear perception of their operating power; we can judge of them only from their consequences.

CLXV. In the brains of those who die of epilepsy are often found tumors, abcesses, thickening of the membranes, and tubercles; effusions of serum are also frequently detected, of which I shall have occasion to speak hereafter. In a memoir lately presented to the academy of Paris, by Dr. Desmoulins, there is a relation of an autopsy, where the facial nerves of a man who had died of epilepsy were greatly enlarged; the perforans casseri and median nerve of the left arm were likewise thicker than the same nerve of the right arm. No inference can be drawn from such a circumstance, because the quantity of vital force is not regulated by the quantity of nervous substance, but by its division, and thereby multiplying its points of contact with the blood-vessels.

CLXVI. When epilepsy is caused by injuries or disorganization, it is almost constantly incurable. It is obvious that the practice should be regulated by the nature of the exciting causes, and in general

it is not very difficult to discover whether it proceeds from sedative or stimulating agents.

CLXVII. When it occurs early in life, it is often removed at puberty, or by any other circumstance which gives increased vigour to the vital force. When it arises from strong emotions of the mind, it is sometimes removed by emotions of a different nature; of this, Boerhaave's cure of the orphans at Haarlem is an example.

CLXVIII. Epilepsy was called the Holy Disease by the ancients, from a belief that those afflicted with it were labouring under supernatural influence. Mahomet and Cæsar having both been subject to epileptic fits, it appears that though they sometimes induce fatuity, the liability to them is by no means incompatible with the highest order of mental capacity.

CLXIX. *Convulsions of Chorea.*—The disease commonly called the dance of St. Vitus, from the mummeries of his votaries in the dark ages, consists in numerous angular motions of the extremities and head, from the brain having gradually lost its influence over the voluntary muscles. Besides the impossibility of keeping one position for any length of time, it is usually attended by an obstinate constipation of the bowels.

CLXX. I have only seen three cases of chorea, and in all of them the affinity to paralysis was so

close, that if I had had the treatment of them, my attention would have been directed more to the brain and spinal marrow than to the alimentary canal. Besides removing constipation, purgatives are probably beneficial in causing a derivation from the brain.

CLXXI. Like other spasmodic diseases, chorea has been cured by fever: I might easily illustrate this by a case, but I prefer quoting a general observation of the illustrious Stahl, on the autocrateia: "Hæc est vera illa medicina naturæ, qua, sine medico externo consilio et auxilio, multos sanari jampridem monuit Hippocrates. Hæc est methodus illa autocratica summæ dignitatis ad considerationem, atque pensationem solertissimam adhibendam, qua homines e gravissimis etiam quibuslibet morbis, sponte naturæ, ut loquuntur, mortis periculum evadunt, et ad sanitatem revertuntur."

CLXXII. *Convulsions of Hydrophobia.*—Most of the poisons have something peculiar in their action on the nervous system; the virus of hydrophobia is remarkable for the slowness and the destructive certainty of its operation. The hydrophobic virus is usually communicated by the bite of a rabid animal, which heals like a common wound; and the symptoms of the disorder often do not appear for months afterwards. Gentilis mentions, in a quotation, that hydrophobia has appeared forty

years after the bite had been received. But the symptoms of hydrophobia manifest themselves most commonly in the course of six weeks after the communication of the virus.

CLXXIII. There is an analogy between tetanus and hydrophobia; both arise from local injuries; both seem to become fatal more from the operation of the animal economy upon itself, than from the injury inflicted; and both are attended by paralysis of the pharyngeal muscles.

CLXXIV. Hydrophobia is sometimes symptomatic in fevers; but I am not aware that the saliva is ever virulent in such cases.

CLXXV. All was conjecture respecting the operation of canine virus, till the late memoir of Marochetti, which promises to throw light upon this hitherto dark subject. In 1813, he was desired to attend fifteen persons under the influence of canine virus, in Kijawka, a village of the Ukraine; but at the request of some of the villagers, and on condition that nothing was done without his knowledge, he confided the treatment of twelve of his patients to a peasant in the vicinity, who had acquired great reputation for the cure of hydrophobia. The rustic practitioner examined the lower surface of the tongue every day at least, and as the extremities of the ducts from the sublingual glands became swelled, he cauterized the tumors or pustules, and ordered the

patients to drink a decoction of genista tinctoria. All the twelve persons who had this treatment recovered: two of the fifteen did not take it, and the one that Marochetti himself treated, died. "There is one thing," says Marochetti, "which merits great attention; this is the succession of forerunning symptons observable during the formation of the pustules: towards this stage, the pupil of the eye is dilated and fixed, the look is sad, and there is a slight pain in the head. If the tumors which form under the tongue are not opened, and the virus allowed to escape, it is re-absorbed in twenty-four hours, and the disease runs its usual course." When a rabid animal bites many individuals at once, those last bitten have the disease in a milder form.

CLXXVI. The circumstance to which I would particularly turn the reader's attention in the above statement, is the dilation of the pupil, which plainly indicates diminution of action in the optic nerve. It cannot proceed from the fulness of the blood-vessels, for they are always found in their natural state on dissection. Never having seen a case of hydrophobia, I defer carrying this inquiry further at present.

CLXXVII. *Anomalous Spasms.*—By this term I understand those irregular muscular movements which do not constitute a specific disease, such as the tic, and the cramps to which swimmers are

obnoxious when they continue their exercise too long in cold water. There are several diseases considered as spasmodic by medical writers, where the spasms are, properly speaking, only symptoms of morbid action; such are, syncope, cholera, and the various shades of mental alienation. The convulsions of hysteria are also probably only symptomatic; for though in females it is commonly referrible to the uterus, yet, as it occurs likewise in males, the uterus cannot be regarded as necessarily the seat of the disease.

CLXXVIII. In some instances, one part of the muscular system is convulsed, and another in a state of spasm, at the same moment. A French soldier coming down the rue Copeaux, at Paris, leaned himself against the wall, and was seized with spasm of the sacral extremities; the passengers seeing him ill, supported him in their arms. The mental functions were suspended without any motion of the facial muscles, the trunk and sacral extremities were inflexible, but both arms were convulsed. In twenty minutes he regained his senses, and was able to walk away, though with extreme difficulty. In the suspension of the mental functions and convulsion of the arms, this case resembles epilepsy; and in the rigid spasm of the trunk and limbs, it is near akin to tetanus. Many varieties of convulsion and spasm are to be met with in practice.

CLXXIX. All spirituous liquors, and those medicines called antispasmodics, produce spasm or convulsions when administered in improper doses. In Hindostan, the strychnos nux vomica is said to cause trismus even in horses which browse upon it by accident.

CLXXX. All causes, whether physical or moral, which act powerfully on the nervous system, are injurious to the generation of the vital force. Intense study too long continued, begets quivering and convulsions of the muscles; and when the emotions of the mind are sudden and violent, vitality is sometimes even annihilated: Eli died on receiving intelligence that his two sons had fallen in battle; and Sophocles expired on being awarded the tragic wreath at the Olympic games. In those cases, however, where the mental emotions are of an exciting nature, there is frequently a determination of blood to the brain.

CLXXXI. By thus grouping the causes of spasmodic action of the muscles into stimulants and sedatives, the former have been shown to possess sedative effect when applied to the nervous system beyond a certain degree of intensity; spasm, convulsion, and paralysis are therefore only different degrees of reduction of the vital force.

CLXXXII. By rigid attention to causation in morbid contraction, clear, definite, and scientific rules of practice may be founded. It does not

follow, that when the action of the nervous system is overcome by a stimulus beyond what it can support, still greater stimulants must be applied to renew the vital force. This was the fundamental error of the Brownonian system. Tonics are, however, most commonly requisite after the removal of the exciting cause, even if it be a stimulant.

CLXXXIII. I have combated the doctrines of Haller and Bichat, because they are artificial, inconsistent, and discordant with the phenomena of life, either in health or disease. I have supported other opinions, because they appear natural, consistent, and applicable to practice. Highly as I respect the talents and perseverance of both these physiologists, I cannot consent to be their disciple at the expense of believing self-evident absurdities.

SECTION VIII.

Vascular Irritability.

Motus, circulatorius non est vita, sed tantum instrumentum vitæ.—STAHL.

CLXXXIV. Under the head of vascular irritability, I shall comprehend the motion of the heart, veins, arteries, and absorbents; and the expansion of these organs being nearly allied to muscular expansion, all that has been said on it, will be applicable to the vascular system. A rigid adherence to anatomical connexion, would have brought the irritability of the heart under Visceral Irritability; but the functions of the vascular system, and the motion of the heart, are so immediately related, that it is impossible to consider them separately. The vascular system is a vast collection of tubes, varying in diameter according to the state of the vital force; and all of them are connected with the heart, through the medium of the great trunks from which they branch off, or in which they terminate. The heart thus forms a sort of central point in the

circulation, from which it is convenient to set out. In the application of muscular expansibility to the motion of the blood, I have been anticipated by Dr. Carson; and although I must, in a great measure, renounce my claim to originality in this part of physiology, it was with much pleasure that I perused his work, which is, in my opinion, the best which has been published on this subject since Harvey. Dr. Carson has not, indeed, sought after the cause of expansibility, but he has pointed out its influence on the motion of the blood, with a force of argument, and clearness of demonstration, highly creditable to his ingenuity and judgment. The side blow which he has aimed at Haller's authority, will not, however, be hastily forgiven by those whose knowledge of physiology is confined to their library and the dead subject.

SECTION IX.

Cardial Irritability.

"By the contraction of the ventricles, it propels the blood through the arteries, and by the dilatation of the auricles, it pumps it from the veins."—CARSON.

CLXXXV. The heart is composed of strong muscular fibres, which decussate each other in all directions, and are so interlaced together, as to defy description. They are arranged in such a manner as to form four distinct cavities, which necessarily vary in dimension according to the state of the fibres by which they are formed. The fibres of the heart are eminently endowed with irritability, which is called their systole and diostole; these terms, however, signify nothing more than expansion and contraction.

CLXXXVI. The heart is supplied with nerves from the eighth pair and the great sympathetic.

CLXXXVII. It has been much agitated, whether expansion or contraction of the heart be the active state of this muscle: Haller and Bichat contend

for the latter opinion, and Pechlin and Langrish for the former. As every movement of muscular fibres is action, I can see no valid reason for objecting to either of these opinions.

CLXXXVIII. When the heart of a living animal is cut suddenly from its situation, it continues to expand and contract for some time afterwards; but every other muscle treated in the same manner does more or less the same: so far, then, the heart and the rest of the muscular system are similar.

CLXXXIX. The hearts of fishes retain their irritability longer than those of warm-blooded animals, and expand for hours after separation from the body: but their expansibility becomes less and less towards the termination of motion. The cavities of the heart being formed of an expansive texture, it is manifest that their capacity must depend immediately on the state of the fibres composing the heart.

CXC. When the vital force is raised by local inflammation, then the muscles are greatly expanded, and then also the expansion of the heart is at its maximum, which is evinced by the increased quantity of blood expelled at each contraction. When, on the contrary, the vital force sinks low, as before death, the muscles lose their expansibility: then also the expansion of the heart decreases, it contracts on a smaller quantity

of blood, and the pulsations become more frequent and feeble.

CXCI. Congestion of blood in the brain, often causes spasm of the muscles; it likewise frequently lessens the expansion of the heart, and consequently the quantity of blood in each pulsation. The abstraction of blood in such a case, restores the expansibility of the muscles, and increases the fulness and strength of the pulsations.

CXCII. These facts are so many direct proofs that the irritability of the heart and the whole muscular system depends on the same causes, and is regulated by the same laws, the power of voluntary contraction alone being excepted. To these facts, indeed, may be opposed an abundance of authoritative assertions, but not one conclusive apposite fact, that I know. Expansion of the muscles invariably precedes contraction; but with the greater number of physiologists, expansion has been nothing, and contraction every thing; hence has arisen a speculative physiology, which is neither amusing in itself, nor applicable to any earthly purpose but book-making.

CXCIII. The expansive force of the heart is very considerable, which may be ascertained by endeavouring to prevent its expansion by compression with the hand.

CXCIV. The heart being enveloped in the pericardium, and moistened by the liquid contained in this membrane, cannot be said to move in a vacuum; but it should be recollected, that the thorax being an air-tight cavity, and the left lung not pressing equally on the whole of the pericardium, the periphery of the heart is not subject to the whole pressure of the atmosphere. This arrangement of parts in which the heart is placed, must considerably aid the natural expansibility of its fibres, and augment its power of suction.

CXCV. The influence of the heart's expansion on the fluids, within the sphere of its action, appears extremely plain, if we reason simply from cause to effect, or *vice versâ*. Supposing the right auricle to have contracted, the moment that it again expands, a temporary vacuum is formed, which is instantly filled with blood from the venæ cavæ, upon the plain laws of hydrostatics. This suction of the auricle causes an undulatory motion in the blood of the venæ cavæ, which Haller calls contraction of these vessels. It is obvious that the quantity of blood drawn from the venæ cavæ must depend on the degree of expansion in the fibres of the auricle.

CXCVI. The filling of the auricle speedily alters the state of its fibres, the blood not only neutralizes the expansive force, but communicates a

contractile power to them; the capacity of the auricle is thus suddenly diminished, and its parietes press with violence on its contents. By this contractile effort of the auricle, the blood is partly forced back into the venæ cavæ, but by far the greater part passes into the right ventricle, which is expanded to receive it, and from which its return is opposed by the tricuspid valve. The blood rushes into the ventricle with great force, not simply from the impetus communicated by the contraction of the auricle, but also from the suction of the expanded ventricle.

CXCVII. In the ventricle, the blood produces the same effect as in the auricle, and is propelled vehemently into the pulmonary artery. The expansion of the right ventricle would suck back the blood from the pulmonary artery, did not the semilunar valves, which are bellied out on their cardiac aspect, prevent its return.

CXCVIII. The pulmonary artery divides into an infinity of small branches, which are ramified on the air-cells of the lungs, where the venous blood is decarbonized and changed to a bright red colour. The blood passes most freely through the lungs during inspiration; but as this position has been denied, I shall offer some arguments in its defence, when I come to respiration.

CXCIX. The blood, in passing through the capillaries of the lungs, parts with a quantity of

carbon, some water, and a very little hydrogen; and is thus changed from venous to arterial blood; the oxygenation which it was supposed to undergo, by coming in contact with the air, is a very pretty theory, but is unhappily not true. The four pulmonary veins which convey the blood back to the heart, are formed by the junction of numerous small branches, which must in some degree be influenced by the motion of the lungs.

cc. The left auricle and ventricle are separated by the mitral valve, and follow the same order of expansion and contraction which has been described. The systole and diastole of the two auricles are synchronous, and the two ventricles expand and contract at the same moment; but the auricles are expanded when the ventricles are in a state of contraction, and *vice versâ*.

cci. It is evident that the expansion of the ventricles does not operate solely on the blood contained in the auricles; and were it not for the obstruction of the semilunar valves at the orifices of the aorta and pulmonary artery, the suction of the ventricles would draw the blood from them as readily as from the auricles; the diastole of the ventricles must therefore subject the semilunar valves to considerable pressure from the reflux of blood at the commencement of the aorta and pulmonary artery. The eddy thus produced in the blood, at the cardiac extremities of these great

vessels, readily explains the formation of the sinuses of Valsalva.

CCII. The French physiologists have had long disquisitions on the unequal capacities of the cavities of the heart, but they do not seem to have arrived at any thing certain on the subject. Senac's idea that the right ventricle is not so completely emptied by its systole as the left, appears plausible; for as both cavities transmit the same quantity of blood, it is reasonable to suppose that a residue of it should be left in the right ventricle after it has contracted. Some have alleged that the size of the right ventricle is affected after death by the contraction of veins propelling the blood into it.

CCIII. When the two ventricles of the heart contract, its apex strikes against the fifth and sixth ribs; this percussion may generally be felt externally, but lying on the right side, or deep inspiration, renders it either obscure or imperceptible. During infancy, the pulsations of the heart rise as high as a hundred and twenty in the minute, in old age they sink as low as sixty.

CCIV. The expansion and contraction of the cavities of the heart are audible externally, either by the application of one ear opposite the region of the heart, or still better by the stethoscope invented by Laennec. " In a well-proportioned

heart," says this author, " the alternate contractions of the ventricles and auricles, examined by the aid of the stethoscope, and touching the pulse at the same time, present the following phenomena: The moment the artery strikes the finger, the ear is gently raised by a movement of the heart isochronous with that of the artery, and accompanied by a dull yet distinct sound. This phenomenon is owing to the contraction of the ventricles. Immediately after, and without any intermission, a sharper sound like the lapping of a dog, announces the contraction of the auricles." This is what Laennec calls the rythm of the heart, a knowledge of which is extremely useful in the diagnosticks of diseases of this organ.

ccv. As the state of the pulse depends essentially on the expansion of the cardiac cavities, it is necessarily diversified by an infinity of contingent circumstances. Generally speaking, however, the pulse is full and strong in all inflammatory diseases, but small and weak in fevers of the typhoid type. But the sympathy of the heart with the other important organs, is not uniform, for in inflammation of the abdominal viscera, the pulse is never so full as in pneumonia or pleuritis. There is also a depression of the pulse from excessive inflammation and congestions of blood, which is extremely embarrassing to the half-educated practitioner.

CCVI. In the cold-blooded animals, the brain has so little influence on the heart, that many of them have lived for weeks after its removal, without having seemed to suffer any material injury; and even in the human species, acephalous fœtuses show that the functions of the heart may be carried on in utero, independent of the brain. But all strong emotions of the mind, whether of a pleasing or disagreeable nature, affect the movements of the human heart, which has therefore been regarded as the seat of the passions. Severe and lasting grief commonly induces aneurism of this organ, and is expressly called by the populace a broken heart. In France, for some years after the revolution, which tore asunder so extensively the ties of kindred and friendship, the number of diseases of the heart was unprecedented.

SECTION X.

Arterial Irritability.

CCVII. It has been a favourite notion with many eminent physiologists, to lay the whole stress of the circulation on the heart, and to regard the arteries as inert tubes; but they are so immediately connected with all the important operations of surgery, and have been so frequently brought under consideration, that their real functions are now pretty well understood. The animal economy is a vast assemblage of organs, where each performs its peculiar office, and yet concurs with the rest in one grand design. The operation of one organ cannot, therefore, be magnified at the expense of another, without a jar in some part of the system.

CCVIII. All the arteries are derived from the aorta, and are in fact only divisions and subdivisions of it. The coats of the aorta are strong and dense in the vicinity of the heart, but where it divides into branches, they become thin and

more elastic. If the coats of the aorta did not possess considerable solidity, they would be inadequate to resist the impetus of the blood, and preserve the natural tubular state of this conduit. The aorta and its largest branches must therefore be almost passive in the motion of the blood, for unless their caliber vary by alternate expansion and contraction, they would be incapable of communicating any moving power to the fluid which they contain.

CCIX. If the blood moved solely by the impulsion derived from the left ventricle of the heart, it is obvious that the velocity and strength of the circulation should be unchangeable in vessels of an equal caliber, and at an equal distance from the point of motion; but this uniformity in the circulation never exists in diseases of local debility, or excitement.

CCX. In local inflammation, the pulsations of the arteries of the part may become preternaturally strong and full, without any change in the motion of the heart; the whole of this local increased action must consequently be owing to the irritability of the arteries. Sometimes the pulsations of the arteries do not even correspond with the contractions of the heart: "Thus, in whitlow of the finger," says Richerand, "the radial artery pulsates a hundred times in the minute, while on the sound side its beats are only seventy, and

perfectly isochronous with the pulsations of the heart.

CCXI. The pulsations of the radial arteries frequently differ in the same individual: in hemiplegia the pulse is always feebler in the paralytic arm than in the sound one; at least to this general law I have known only one exception, which has already been mentioned. (XI.) This difference in the pulsation of the two radial arteries, cannot be owing to the heart, which gives the same impulsion to the blood which proceeds to the paralytic arm, as to that which goes to the sound one.

CCXII. I readily admit, that the heart is the primary agent in the circulation of the blood in the human species; but in those fœtuses which are without this organ, the motion of the blood must necessarily be caused by the irritability of the veins and arteries, for vitality without motion is impossible. I do not wish to undervalue the action of the heart, I merely contend for the co-operating power of the arteries.

CCXIII. Although the aorta, from the compactness of its texture, has little irritability, the extreme arteries, and even the considerable trunks, possess it in great perfection. When the blood ceases to flow into an artery, it becomes an impervious ligament; which shows that the expansion of the arteries is in part owing to mechanical distention; but it is to be recollected, on the

other hand, that the quantity of the blood which they contain, is dependant on their vital expansibility. I shall endeavour to demonstrate this allegation by analysis, by synthesis, and by experimental facts.

CCXIV. In the cold stage of an ague, when the vital force is low, the pulse is feeble; but in the hot stage, when the vital force is restored, the expansibility of the arteries, and the strength of the pulse, are augmented. The same series of phenomena arise from extremes of cold or heat. The extreme arteries are always morbidly expanded in local inflammation; but by reducing the vitality of the part, either by bleeding or topical application of cold, the arteries usually lessen in size, as the vital force decreases.

CCXV. In whatever part of the body the animal temperature is lower than natural, there also the pulsation and expansibility of the arteries are lower than natural; and if the animal heat be locally or generally augmented, so also will be the expansibility of the arteries.

CCXVI. That the contraction of the heart is not the cause of arterial expansion in the above instances, may be established by experiment. When the vital force of a paralytic arm is raised, by applying nitrate of silver in the axilla, the natural expansion of the brachial artery is

restored through all its ramifications; the increased arterial expansibility is here local, being confined to one arm. If the vital force in a case of intermittent fever, be raised generally, an hour or two before the accession of the cold stage, by applying lunar caustic to the spine, the whole arterial system retains at least its natural expansibility. These facts must convince every unprejudiced and reflecting mind, that the vital force contributes materially to the expansibility of the arterial system; but what portion of it belongs to the force of the heart, and mechanical distention by the blood, and what to the vital force, it is impossible to ascertain—calculation is not applicable to the laws of vitality.

CCXVII. The influence of the mind on various parts of the arterial system, is a further proof of the dependance of its irritability on the vital force. The pudic arteries may be thrown into violent action solely by the imagination, and every one has observed the effects of fear and shame on the colour of the cheeks. Violent emotions of the mind, which raise the vital force, have sometimes even arrested the cold stage of an intermittent fever. Pliny mentions the case of a Roman consul, who was radically cured of an ague, by fighting a battle on the day of its accession. Sometimes even general expansion of

the arterial system may proceed from various passions: Leo X. died of a fever caused by joy at the capture of Milan.

CCXVIII. The expansion of the arterial system is synchronous with the contraction of the heart.

CCXIX. No arguments are required to prove that the blood causes contraction in the arterial system; the increased impetus of the blood in an artery going to a local inflammation, and fœtuses without hearts, are positive evidences of contractibility, which no sophistry can perplex, no experiments annul.

CCXX. *Acute inflammation.*—When the arterial expansibility of an organ is increased to such a degree, that there are present, pain, redness, swelling, and preternatural heat; it is said to be in a state of inflammation. This morbid condition may be accomplished by causes which either augment or diminish the vital force of the part.

CCXXI. When the vital force is locally much augmented, as in a scald, the calibers of the extreme arteries are enlarged, and elicit a greater quantity of blood from their trunks, to the part affected, which inflames forthwith. The capillaries are more expansible than the extreme arteries, and participate largely in the morbid expansion of inflammation; and some have even supposed it situated exclusively in them.

CCXXII. Inflammation may again be brought on from decreased vital force of an organ. If the hand be exposed to severe cold, the collapse of the capillaries and extreme arteries of the fingers, obstruct the passage of the blood into the veins; but the brachial artery still continuing to receive its ordinary quantity of blood, becomes more turgid, and contracts with additional force, which, by degrees, mechanically distends the extreme arteries of the fingers. The stoppage of the blood speedily acts on the nerves of the part; the capillaries, in their turn, dilate to a morbid extent, and the blood rushes into them from the turgid arteries, and throbbing pain, redness, swelling, and increased heat, are the consequences.

CCXXIII. Stimulating causes produce inflammation, from accumulating the blood in the part, from morbid expansion of the extreme arteries; sedative causes do the same, by stopping the progress of the blood through the capillaries. This is the mechanism of acute inflammation, so far as I am able to judge; and upon these principles may be explained the manner in which heat and cold produce the same ultimate effects on the extreme vessels. When the blood accumulates to an excessive degree in the dilated arteries, it is apt to annihilate the functions of the nerves, and whenever this is the case, mortification certainly follows.

SECTION XI.

Venal Irritability.

CCXXIV. According to the laws of hydraulics, the motion of the blood should become slower in passing from the capillaries into the veins, in consequence of the larger caliber of the latter vessels; but here the laws of irritability counteract the laws of hydraulics.

CCXXV. The extreme arteries are more expansible than their trunks, the capillaries than the extreme arteries, and the veins than the capillaries. On the back of the hand, the veins are at one time scarcely visible through the skin; at another, they are gross as goose-quills. Immersion of the hand alternately into hot and cold water, shows the expansibility and contractibility of the veins in great perfection. What, then, is the effect of this superior irritability of the veins on the circulation?

CCXXVI. It is quite plain, that if one end of a tube, whose caliber is incessantly changing, be in contact with a liquid, expansion of the tube, as well

as capillary attraction, must draw the liquid into its cavity; and contraction of it forward the fluid along its canal. Such is the relation of the veins with the blood in the capillaries; the expansion of the veins sucks the blood from the capillaries, and their contraction propels it in the direction of the heart, as being the least resisting course.

CCXXVII. But the irritability of the veins is not the only cause of motion in their tubes; the impetus of the heart is not wholly expended on the arteries; for a pulsation, synchronous with that of the heart, has been, though very rarely, observed in the veins. A case of this kind is recorded by Dr. Parry, of Bath.

CCXXVIII. The mechanism of the venal valves is admirably contrived to secure any counter motion of the blood in the veins, admitting its free passage in the direction of the heart, and effectually opposing its reflux.

CCXXIX. As the right auricle pumps up the blood from the venæ cavæ, the pressure of the atmosphere upon the surface of the body, must contribute to the progressive motion of the blood from the small veins to the great venous trunks.

CCXXX. The old anatomists knew of no absorption but by the venous system. John Hunter denied the absorbent power of the veins; but this opinion, which was, in fact, incompatible with the irritability of these tubes, has recently been

refuted by M. Magendie. The following experiment conveys an accurate notion of absorption by the veins: "M. Delille and I separated a dog's thigh from his body, leaving only the crural artery and vein untouched, which preserved the communication between the thigh and the trunk. These two vessels were dissected with the greatest care; their cellular coat was removed, for fear that it might contain some lymphatic vessels. Two grains of a very strong poison (l' upas tieuté) were then forced into its foot; the effects of this poison were altogether as rapid and as intense as if the thigh had not been separated from the body; in fact, they showed themselves before the fourth minute, and the animal was dead before the tenth."

CCXXXI. M. Magendie discountenances the idea, that venous absorption is a proof of an attracting power in the veins; but it is very obvious, that when the veins draw extraneous bodies into their cavities, they must do so by some power of their own, and irritability is quite adequate to explain this phenomenon.

CCXXXII. Three forces, then, combine in moving the blood in the veins, viz. the vis a tergo communicated by the heart, venal irritability, and the suction of the right auricle of the heart; but the quantity of power which each of these forces contributes to the circulation, is unknown.

CCXXXIII. The motion of the blood is generally allowed to be slower in the veins than in the arteries. Dr. Thomson says, that he has seen the globules of blood in the veins, which he never could observe in the arteries. This is the strongest proof of a slower motion in the veins than in the arteries, that comes within my knowledge.

CCXXXIV. *Chronic Inflammation.*—The capillary vessels are extremely liable to disease, from the facility with which they are affected by changes of temperature. The capillaries and the extreme arteries are the situation of acute inflammation. Chronic inflammation is, in most instances, confined to the capillaries; that is to say, the arteries may resume their natural state of action while the capillaries continue turgid with blood. This morbid state, I am of opinion, is kept up by defective venous irritability.

CCXXXV. Chronic inflammation is often without pain or increased heat, symptoms which are never absent in acute inflammation.

CCXXXVI. Increased expansibility of the extreme arteries, constitutes the most material part of acute inflammation; abstraction of blood is therefore the most effectual method of reducing it: but chronic inflammation, depending chiefly on defective expansibility of the veins, receives only a momentary relief from bleeding. Acute Hepatitis is relieved by depletion of the blood-vessels;

but when the same disease becomes chronic, stimulants are more beneficial than an opposite treatment. The same observation is applicable to ophthalmia, swelling of the joints, and almost every chronic inflammation. From the superior expansibility of the veins, stimulants moderately applied in chronic inflammation, may augment the calibers of the veins, without affecting the diameters of the arteries. By this superior expansibility of the veins, they are thus enabled to draw the blood quickly out of the capillaries, and equalize the circulation of the inflamed part with the rest of the system.

CCXXXVII. Most commonly, chronic inflammation is preceded by some increase of arterial action; but sometimes it arises wholly from defective venal expansibility. I shall illustrate this position by neuralgia of the sacral extremities, a disease of extreme interest, and very imperfectly understood.

CCXXXVIII. *Neuralgia.*—This disease is caused by exposure to cold, at least I have never known a case of it arise otherwise. It begins with a numb pain extending from the trochanter major along the course of the sciatic nerve, as far as the outer ankle. Its accession is sometimes so instantaneous, that the patient finds himself incapable of walking, without the least previous warning of approaching disease. As the muscles waste from the commencement of neuralgia, this may be

called its paralytic stage, and frequently it advances no further.

CCXXXIX. Sometimes, however, in the course of a few weeks or months, neuralgia passes into the second or inflammatory stage. The pain which was obtuse in the paralytic, becomes excessively acute in the second stage; the muscles continue wasting, and are extremely sensible to the touch; but they bear pressure when it is applied generally with a bandage.

CCXL. The disease is now subject to nocturnal exacerbations, which commence in the evening, and last six or seven hours; during which, the patient frequently utters loud and doleful screams; and when he drops asleep, exhausted with agony, it is only to awake to renewed misery; the constant gnawing-pains, like the vultures of Tityus, permit him no interval of waking tranquillity. In this aggravated state of neuralgia, the patient is reduced to the last degree of emaciation; but the diseased thigh is sometimes an inch and a half smaller than the other. Sometimes it is attended with ansarca about the ankle.

CCXLI. In the first stage of neuralgia, the vital force is simply diminished by the influence of cold on the sciatic nerve.

CCXLII. But every variation of the vital force has repeatedly been proved to cause a corresponding variation in the expansibility of all the soft fibrous

texture, according to the nature of its structure; and the veins being more expansive than the arteries, are consequently more readily affected by variations of the vital force.

CCXLIII. In neuralgia there is a diminution of arterial as well as venal expansibility, but the delicate veins of the sciatic neurilema being most easily affected, they collapse, and are unable to absorb the blood from their capillaries, which become distended, causing intolerable pain of the sciatic nerve. I have never known this pain extend to the divisions of the sciatic nerve beyond the ankle, where the points of contact between the blood-vessels and divisions of this nerve become multiplied.

CCXLIV. The distention of the capillaries with blood not being from increased arterial action, detraction of blood seldom gives even temporary relief; the small veins of the neurilema remain obstinately contracted, and depletion may be carried to any length, without equalizing the circulation.

CCXLV. When the expansibility of the veins of the sciatic neurilema is renewed, by restoring the action of the nerve with the nitrate of silver, the disease is removed, by absorption, in a few days. But if the application of the lunar caustic be so great as to affect the expansibility of both the arteries and veins, the pain is more severe for

a day or two; but on the fifth or sixth day, the expansibility of the arteries sinks to its natural state, while that of the veins continues preternaturally augmented till the tenth; before which period, the capillaries are usually restored to their natural state by venal absorption. It is precisely upon this principle, of keeping up a corresponding degree of expansibility between the arteries and veins, that stimulants are beneficial in scalds.

CCXLVI. Dr. Sillar, who has had extensive practice in neuralgia of the sacral extremities, informs me, that it is his opinion, if the lunar caustic could be applied in such a manner as to raise the expansibility of the veins to its healthy pitch, without influencing that of the arteries, the relief would generally be almost immediate. I feel much disposed to adopt this opinion; in favour of which, he possesses several beautiful cases in his Journal.

CCXLVII. The paralytic stage of neuralgia being merely a temporary diminution of the vital force, the patient often feels himself more than half cured when the practitioner has finished the eschar. It is of great consequence to cure neuralgia of the sacral extremities during the first three months of the inflammatory stage; for when it has lasted more than a year, the patient is very obnoxious to relapse.

CCXLVIII. In chronic inflammation of the joints, there is often a combination of arterial plethora

and defective expansibility of the veins; but the increased action of the arteries is frequently the result of harsh treatment.

CCXLIX. It is not "in form and moving" alone, that man is "express and admirable." When we consider the exquisite mechanism by which the uniformity of the circulation is preserved in health, and restored from disease, it is impossible not to feel the most profound and solemn reverence for the Wisdom that designed this complicated fabric, and harmonized its motions.

SECTION XII.

Absorbent Irritability.

CCL. The first accurate opinion relative to the action of the absorbent system, is that promulgated by Dr. Fullarton, in a Thesis published at Glasgow, in 1800. He is said to have alleged, that the absorbents act by suction; but as I have never seen his Thesis, I know not upon what grounds he established his opinion, and I merely mention it here to preclude any charge of plagiarism hereafter.

CCLI. The absorbents are a sort of succedaneous venous system; they possess valves like the veins, but their action is simpler than that of the venous system; in them there is no vis a tergo to distract the physiologist, the fluids move in them by the compound motion of their irritability. The lacteal absorbents, and the lymphatics of the skin, have no communication with the heart but by the vena cava superior, consequently no motion of the heart can apply to the action of these parts of the absorbent system.

CCLII. Absorbents have been found in the texture of every organ, except the brain; and there is every reason to suppose they exist in it also, though they have not hitherto been detected. Their tubes are extremely small and numerous, which unite and form considerable trunks. This distribution of their tubes is favourable for capillary attraction.

CCLIII. It is almost universally admitted at present, that the motion of the lymph and chyle in the absorbents, is the effect of a contractile power which they possess: but how a contractile power alone can suffice to draw up and move onwards a column of fluid in a tube, is, I confess, to me quite incomprehensible. It is easy to conceive, that when the mouth of an absorbent contracts upon a fluid, it must be impelled forward in its canal; but if the mouth of the absorbent remain contracted, nothing can be plainer, than that the chyle or lymph will be effectually excluded. This position may be elucidated by a rather homely example: the lips form the orifice of an absorbent upon a large scale; but let a person close them firmly, by contracting the orbicularis oris, and try to draw any fluid into his mouth, he will never succeed till the orbicularis is relaxed. If the absorbents have only a contractile power, their mouths would continue in a state exactly similar to the lips of a man trying to

drink with his orbicularis oris contracted; and no fluid could ever enter their tubes even by capillary attraction. If the absorbents possess a contractile power only, they would be entirely useless as active conducting canals.

CCLIV. But the absorbents are subject to the common laws of irritability as in the other organs.

CCLV. When the vital force is greatly diminished by excessive hemorrhage, anasarca of the extremities follows, from the reduced expansibility of their small absorbents; and this is an excellent example of what contractibility would effect without expansibility.

CCLVI. In hemiplegia, the reducement of the vital force necessarily diminishes the expansibility of all the blood-vessels on the paralytic side; but this occurs unequally; for owing to the superior density of the arterial coats, they do not, for some time, reach their maximum of morbid contraction. But the thin delicate coats of the absorbents contract more speedily, and the lymph effused by the exhalants is often not pumped up quick enough by the lymphatic absorbents. Anasarca is then the consequence, and will continue to exist till the expansibility of the arteries, veins, and absorbents, arrive at a sort of paralytic equalization.

CCLVII. I have seen the anasarca of a paralytic limb removed by restoring its vital force; but

I shall elucidate the irritability of the lymphatics in the more common disease of white swelling.

CCLVIII. It will scarcely be denied, I apprehend, that white swelling of the knee-joint proceeds from defective lymphatic absorption; or, in other words, morbid contraction of the lymphatic tubes. I shall endeavour to place this conclusion in a simple and clear light, by a very easy experiment.

CCLIX. When a lunar caustic eschar is applied to a white swelling of the knee-joint, the expansibility of the absorbents is renewed; but although there be generally no inflammation except at the edge of the slough, yet the extreme arteries of the joint are also a little expanded the first three or four days. But by the twelfth day of the eschar, the swelling has subsided sometimes a full inch by absorption alone; for lunar caustic causes scarcely any discharge of pus. The sudden abstraction of the effused fluid, in a diseased joint thus treated, cannot be supposed to result from the lymphatics alone; the veins, doubtless, contribute material assistance: but the principle of venal and lymphatic absorption is the same.

CCLX. Cantharides have also a very powerful effect upon the absorbents; a blister applied to the scrotum, in hydrocele, throws its lymphatics into a state of great activity, and the effused fluid is quickly taken up by their expanded tubes; but when the artificial excitement is at an end, the

lymphatics of the testicle resume their morbid contracted state, and the serum again accumulates in the tunica vaginalis.

CCLXI. Serous effusions again proceed from increased action of the extreme arteries, and occur most frequently in inflammation of the serous membranes. The efficacy of bleeding and digitalis, in lessening the action of the arterial system, is so generally acknowledged, that it would be superfluous to bring proof in support of their utility.

CCLXII. Whenever the expansibility of the exhalants rises above that of the absorbents, serous effusions take place; the same occurrence happens when the expansibility of the absorbents falls below that of the exhalants. Thus, on the equality of irritability in the extreme arteries, veins, and absorbents, depends the equation and distribution of the fluids in those tubes; and the superior expansibility of the veins and absorbents, when effusions do occur, tends to carry them off, and re-establish the equality of the circulation.

CCLXIII. The lymphatics proceeding from an abcess have been found replenished with pus in place of lymph. The absorption of mercury and other medicines from the skin, show that they are capable of receiving a variety of substances.

CCLXIV. Upon the whole, it appears certain, that when the orifices of absorbents in contact with a liquid, expand, part of it must rush into

their tubes, by suction and capillary attraction, and that their subsequent contraction must forward it from branches to trunks, agreeably to the laws of hydraulics. The valves of the absorbents prevent their small branches from being at any time overburthened with a long column of fluid.

CCLXV. When the delicacy of the expansibility of the small absorbents is considered, the serous effusions so frequently found in spasmodic diseases can be readily explained; the same alteration of the vital force which induces morbid contraction of the muscular system, throws the absorbents into the same state.

CCLXVI. The absorbents which rise from the inner surface of the alimentary canal, have been called lacteals, from their containing chyle. The motion of the chyle in the lacteals is very rapid; for when they are wounded, it runs out with very considerable velocity.

CCLXVII. An opinion now begins to prevail, that the lacteals absorb nothing but chyle, and that the other substances which are taken from the alimentary canal, are absorbed exclusively by the veins. John Hunter, however, states expressly, that he found both indigo and musk in the lacteals; a statement corrobarated by Fordyce, Haller, and Blumenbach. Hallé, Magendie, Tiedmann, Gmelin, have never found odorous

or coloured bodies in the lacteals, but always in the veins. It does not seem very clear that this subject deserves any very great consideration; for these contradictory facts only infer, that sometimes the lacteals absorb coloured fluids, and sometimes they do not. The nature of the substances, and the difference of the animals employed, in the experiments of these physiologists, will probably go some length in explaining their discordant results.

CCLXVIII. If the chyle be coloured with a mild vegetable substance in the intestines, it is not very easy to conceive a power in the lacteals, of separating the colouring matter from the chyle; but it is easy enough to understand why the lacteals of a graminivorous animal should reject alcohol and essential oils. Although I am decidedly in favour of the absorption of various substances by the lacteals, yet I must confess that in one attempt made by Dr. Sillar and myself to prove this opinion, we were disappointed.

CCLXIX. Sir Everard Home found rhubarb in the urine of an animal whose thoracic duct had been tied previously to swallowing that medicine, which must consequently have found its passage to the bladder by the veins.

CCLXX. When the thoracic duct of a dog is tied, its coats contract on its contents with violence sufficient to rupture themselves; but even Haller himself conceded contractibility to this tube.

SECTION XIII.

Visceral Irritability.

CCLXXI. Although the functions of the different viscera are extremely dissimilar, yet there is a convenience in studying their irritability in the order of anatomical demonstration. Under this genus of irritability, I shall therefore include the motions of the brain, the iris, the lungs, the alimentary canal, the bladder, uterus, and penis. These organs so far resemble each other, that they are all composed of a fibrous texture that possesses irritability, though in very different proportions in its respective organs.

CCLXXII. The heart has been excluded from this genus, as forming part of the vascular system, of whose functions it would have been impossible to treat with any degree of consistency separate from the primum mobile of the circulation. The irritability of the glands might also have been accurately brought under visceral irritability; but as their structure is not fibrous, and to treat of their functions would swell my work to an unnecessary size, they are left out.

SECTION XIV.

Cerebral Irritability.

CCLXXIII. Philosophers have, in all ages, admitted an intimate relation between the physical and moral nature of man; it is therefore not a little strange, that such a quantity of sarcasm should have been heaped upon Gall and Spurzheim, for bringing, with immense labour, this relation into a more tangible shape. The kind of ridicule now levelled at phrenology, was, in former times, liberally bestowed on chemistry, astronomy, and Christianity itself; and like them, it will be likely to prosper under persecution —truth shines brightest from the collision of opposing sentiments.

CCLXXIV. The Baroness de Stael has truly observed, that every discovery appears absurd at its first announcement; the new conclusions are tried by the test of known principles, while it is precisely by abandoning old principles, especially if they be false, that new conclusions are brought to light. Man feels a sort of selfish regard for the doctrines which he imbibes in his youth; he

feels himself, as it were, personally attacked when they are assailed: it is a most difficult lesson to unlearn error; and to acknowledge it, requires no inconsiderable share of magnanimity. A discoverer has to combat the prejudices of mankind, as well as the difficulties of science; such, at least, has been the fate of Gall and Spurzheim. Fanatics have assailed them, as being irreligious; while they have only shown, that the moral law of the Evangelists is the best adapted to the physical and intellectual capacities of man; and have, in fact, drawn from natural history new and powerful evidence of the divine origin of Christianity. Moralists have railed at them, as confounders of right and wrong, while they have been only laudably employed in pointing out a method by which man may become more easily acquainted with the predominant propensities of his nature, without the instructive, but often painful, lessons of experience. The sages of antiquity; the legislators, philosophers, and divines of modern times; have all added to a knowledge of the general nature of mankind; but phrenology shows the individual to himself, setting his natural character naked before his eyes.

CCLXXV. Gall and Spurzheim allege, that different parts of the brain are destined for certain specific purposes, and that each pair of nerves is a separate system, communicating together at the

medulla oblongata. But I am here only to regard phrenology in so far as it is connected with the irritability of the brain.

CCLXXVI. The white substance of the brain is distinctly of a fibrous texture, which may be traced from the medulla oblongata into all the convolutions; and according to this manner of dissecting the medulla oblongata, is the origin of the brain and cerebellum, and forms a common centre of communication in the nervous system. Acephalous monsters, and comparative anatomy, evince that vitality may proceed without any assistance of the brain, whose office in the human species is more of an intellectual than of a vital description.

CCLXXVII. The operation of the brain, in the production of ideas, will, in all probability, for ever defy our researches; as it is impossible to carry experiments into the delicate structure of this organ, even in the lower animals, without previously destroying its natural connexions; induction is therefore the only means by which any knowledge of the irritability of the brain can be obtained. As its white substance is fibrous, it is reasonable to suppose it is possessed of mobility When the fibres of any other organ are kept long in one position, an uneasiness is produced, and a desire to change their state; the same thing occurs in the brain: when the attention is long directed

to one subject, a sensation of fatigue is felt; and when the ideas are turned into another direction, a sense of satisfaction assumes the place of uneasiness. The inference to be drawn from this circumstance is, that when any particular thought occupies the mind for a length of time, the fibres of a certain part of it are in an artificial state, and become relieved by employing a different part of the brain on a different subject. Long continued thought is not confined to mere lassitude of the brain; it is not unfrequently attended with convulsive motions of the muscular system. Every thing, therefore, tends to prove, that in any particular train of thoughts, or fixed ideas, there is a strain on some particular fibres of the brain. Analogy consequently supports the idea, that the motions of the white substance of the brain resemble, in some degree, the irritability of the muscles; and beyond analogy I dare not advance.

SECTION XV.

Irritability of the Iris.

"Ita iris manifesto constringitur non propria vi quæ non sit irritabilis, sed a retinæ irritatione."—HALLER.

CCLXXVIII. The simplest subject becomes obscure, when involved in the double perplexity of sophistry and invalid facts. Haller, it appears from the quotation at the head of this article, relinquished his irritability in the iris; but, by a curious perversity, he calls expansion of the iris contraction, to make its motion square with his theory of irritability. The errors of a great man find followers enough; the effects of what some Continental authors call tonicity, are in great part owing to expansibility.

CCLXXIX. The colour of the iris has been alleged to proceed from the pigmentum on its central aspect. In the inhabitants of the torrid zone, the iris is usually of a dark colour; it is whitish and almost transparent in the Albino; in cold countries it is most commonly of a light hue. Some assert, that the colour of the eye-lashes and the

iris is the same; but there is little uniformity in this respect.

CCLXXX. The iris is a flat circular ring, whose fibres converge like truncated radii, from the circumference of a circle towards its centre; an opening, called the pupil, is thus left for the passage of the rays of light to the retina. Some authors have asserted the existence of circular fibres in the iris, which draw the central ends of the radiated fibres together, like a sphincter. Haller's observation on this head, is made with all the candour of a philosophic mind: "Verum non oportet fabricas excogitare, quas sensus non confirmant."

CCLXXXI. If the alternate expansion and contraction of the iris depends on circular fibres, its irritability is quite an anomaly in the animal economy; their existence, in fact, would imply that the optic nerve communicates to the fibres of the iris an expansive and contractile power at the same instant, which is incomprehensible. If the pupil were lessened by the contraction of circular fibres, it is evident that the central points of the radiated fibres would be drawn in a lateral direction, whereas they move invariably in straight lines. Besides, in the lower animals, the iris is not always circular. When the iris of a cat is exposed to a strong light, the central ends of its inner and outer fibres arrange themselves in

parallel straight lines, and the pupil resembles a small incision; but when the animal is carried to a dark place, the pupil resumes its circular shape.

CCLXXXII. Another notion respecting the motion of the iris is, that it expands in consequence of a more copious afflux of blood to it; but how does this afflux happen? or do the fluids possess in themselves the slightest degree of moving power? and unless they have a self-moving force, it is impossible that they can move the iris in this ad libitum fashion. This theory is even more speculative than any that Haller has advanced on irritability.

CCLXXXIII. It is however possible, that long exposure to a strong light may bring on expansion of the blood-vessels of the eye; but in such a case, the afflux of blood is the consequence, and not the cause of expansion. But if in an ordinary light any turgescence of the vessels of the iris did take place, what prevents its being observable in the cat, or in the almost diaphanous iris of the albino?

CCLXXXIV. Bichat admits frankly, that expansion of the iris precedes any afflux of blood to its vessels. "I have left out of this table," says he, "the mode of motion of the iris and corpera cavernosa, a motion which precedes the afflux of blood, and which is determined by it. I have left out,

also the dilatation of the heart; and, in a word, that kind of active vital expansibility, of which certain parts appear susceptible. In acknowledging the reality of this sort of vital motion, I avow that I have as yet no clear or precise ideas on the the relations which unite it with other kinds of motion, nor on the differences which distinguish it from them."—*Bichat, p.* 105, *Sur la Vie et la Mort.*"

CCLXXXV. There is great ingenuousness in these remarks; this celebrated author saw clearly that the motion of the iris, the heart, and the corpera cavernosa, directly contradicted his doctrine of contractilité; but in place of casting about to reconcile the contradiction, he openly confessed, that he did not understand the subject. It is rather strange, that he did not assimilate the expansion of these organs with his "*Extensibilité Animale, and Organique,*" as he would have thus represented the animal economy as in harmony with itself.

CCLXXXVI. As the irritability of the iris is very great, the size of the pupil depends entirely on its degree of expansion. The iris derives its vital force from the optic nerve, for it loses its expansibility when this nerve is destroyed, compressed, or paralyzed. The whole nervous system has its action supported by the blood; but various parts of it are so organized, that they are modified by

particular stimulants; thus, the optic nerve is susceptible of having its action augmented by the rays of light.

CCLXXXVII. Nothing can be simpler than trying the irritability of the iris: expose the pupil to a strong light, the fibres of the iris that instant expand, and the diameter of the pupil is lessened; reduce the quantity of light, their length is diminished, and the pupil enlarged. The iris thus follows the same general law as the skin and muscular fibres, augmentation of the vital force producing expansion, and diminution of it, contraction.

CCLXXXVIII. When there is an afflux of blood to the brain, it sometimes occurs that the action of the optic nerve is raised to a great height; and in all such cases, the expansion of the iris corresponds with the intensity of the vital force. But if the afflux of blood be so great as to diminish the action of the brain by compression, or by whatever mode it acts, and produces paralysis, the optic nerve is sometimes compressed, and the iris becomes also paralyzed, and the pupil is preternaturally large.

CCLXXXIX. Dilatation of the pupil of one eye is thus frequently a symptom of hemiplegia; but it is not confined to the side opposite to the one paralyzed. The case of Deschamp shows, that by raising the vital force, the expansibility of the

iris was renewed with that of the muscles. I have met with three cases besides, where the expansibility of the iris was affected in the same manner. On mature consideration of these cases, I cannot regard the cause of motion in the iris as different from the cause of irritability in the muscular and vascular systems. By the study of theories which multiply the agents of motion in the animal economy, the mind is bewildered, without being either amused or edified.

CCXC. Sometimes the blood is so distributed in the brain, as to cause paralysis of some of the facial muscles; while the iris is only raised to its maximum of expansion. On the contrary, a slight excess of drinking occasionally brings on paralysis of the iris, without affecting any part of the muscular system. Cases of these descriptions are now and then to be met with in large hospitals.

CCXCI. The motion of the iris is regarded by some physiologists, as voluntary in parrots; but, in all probability, their irises are affected by the nearness or distance of the objects on which they are looking; for even the human iris expands when the eye is directed to a near object, and contracts when regarding a distant one; but we do not say, on these accounts, that the motion of the human iris depends on volition.

SECTION XVI.

Irritability of the Lungs.

CCXCII. The air cells of the lungs are spungy, fibrous, and easily compressible: it is in them that the divisions and subdivisions of the *Bronchi* terminate.

CCXCIII. The lungs, according to Helvetius, are composed of numerous small lobules, " which are only bundles of cells inclosed in a membrane proper to each. The cells of one lobule communicate together, and the air passes without difficulty from one into the other; but different lobules have no communication with each other: from this it follows, that all the air contained in each cell, passes out from the whole at the same time."

CCXCIV. Haller denies this opinion of Helvetius; but admits, at the same time, that the air cannot pass from lobule to lobule. In these times, it is generally admitted by the best physiologists of France.

CCXCV. The expansibility of the pulmonary air-cells, is known to depend on the vital force, by dividing the nerves distributed upon them. When the par vagum of a dog is divided in both sides of the neck, the lungs are paralyzed; or, in other words, their expansibility is impaired; the muscles of inspiration dilate the thorax with violence; but the air which enters the lungs, is inconsiderable in quantity; the expirations are hurried, and the animal dies of asphixia.

CCXCVI. The division of the par vagum does not cause complete paralysis of the lungs, as they derive part of their nervous influence from the first thoracic ganglion of the great sympathetic; but it always impairs their expansibility sufficiently to cause death.

CCXCVII. The asthma of medical authors, appears to be simply impaired expansibility of the air-cells, which may, according to Dr. Philips, be restored for a while, by sending a current of galvanic electricity through the thorax; opium, ether, and asafœtida, have often a similar temporary effect.

CCXCVIII. Some years ago, I had occasion to treat a gentleman severely afflicted with asthma; I exhausted his patience by a tedious administration of antispasmodics, but with no permanent advantage, and the disease at last threatened

asphixia. As this patient was quite free from his complaint in winter, he was advised to quit the heated atmosphere of his own house, and to remain a few days on board a ship, anchored in a bay, much exposed to the cold sea-breezes. In five days, the patient was quite recovered. Many practitioners in such a case, would prefer extraction of blood to forcing it upon the diseased organs, by reduction of temperature.

CCXCIX. While the expansibility of the lungs is unimpaired, they fill completely the cavity of the thorax; it is destroyed at death; and as the lungs consequently shrink in bulk, the diaphragm is forced upwards by the pressure of the atmosphere on the parietes of the abdomen. Bichat attributed this state of the diaphragm to the cooling of the air contained in the lungs after death; but this inference should, I apprehend, necessarily imply an interruption of communication between the atmosphere and the air-cells of the lungs. Any trifling diminution of the air by cooling, must have its place instantly occupied by the atmospheric air entering by the usual passage of the trachea.

CCC. It would appear, from Bichat's work on life and death, that he had, on several occasions, found the air-cells contracted to such a degree, that a vacuum was formed, after death, between

the pulmonary and costal pleura. The contractile force of the lungs, in these cases, must have been superior to the weight of the atmosphere; which I should feel much disposed to disbelieve, did it not rest on such high authority.

CCCI. On opening the chests of animals, whether dead or alive, I have always found the pulmonary and costal pleura in contact, except when separated by air or fluid. But Bichat, after asserting the existence of a vacuum between them, argues thus: "if the lung collapsed in the body at the instant of opening the chest, it would be from the pressure of the external atmosphere, a pressure which would expel the air contained in this organ, through the trachea; or if, to stop the egress of this fluid, you shut this canal hermetically, by fixing a tube to it with a closed cock, and afterwards let the chest be opened, the lung equally collapses; then the air had previously escaped. Make, on the contrary, the same experiment on a living animal, and you will always prevent the collapse of this organ, by preventing the escape of the air." These experiments seem to be recorded with all the candour of their great author; but to me, I confess, they appear inexplicable by the cooling of the air after death, unless the trachea were hermetically closed at that period. For further information on Bichat's theory, see his work, *Sur la Vie et la Mort*, 193.

CCCII. On the elasticity and weight of the atmosphere, and the expansibility of the lungs, depends the important function of respiration, the consideration of which may conveniently follow the subject of the present section.

SECTION XVII.

Respiration.

CCCIII. The thorax is an air-tight cavity, divided into two parts by the mediastinum, and capable of dilatation in every direction, except on its dorsal aspect.

CCCIV. The mechanical motions of the thorax are extremely easy to understand. From the oblique direction in which the ribs are articulated with the spine, when the intercostal muscles contract, the capacity of the thorax is enlarged forwards, upwards, and on both sides.

CCCV. But the ribs and their cartilages being of unequal lengths, their mobility is subject to considerable variation. The second rib being longer than the first, necessarily moves in the segment of a circle of larger dimensions than it, and consequently possesses a greater degree of mobility. The mobility of the ribs increases from the first to the seventh, and decreases from the seventh to the last.

CCCVI. Haller thought the first rib motionless; but this is a manifest error, as, during inspiration, all the true ribs, from their attachment to the sternum, must join more or less in the common motion upwards.

CCCVII. In ordinary inspirations, the intercostal muscles alone are employed to raise the ribs; but when the breathing is laborious, the muscles of the neck, attached to the sternum, clavicles and scapulæ, co-operate materially in the enlargement of the thoracic cavity.

CCCVIII. When the diaphragm is in a state of expansion, it has a concave appearance when viewed from the abdomen; but, in a state of contraction, it approximates to a plane. By the contraction, or descent of the diaphragm, (as it is sometimes called,) the capacity of the thorax is enlarged in the direction of the sacrum.

CCCIX. As the contraction of the intercostal muscles and the diaphragm, is simultaneous, all pressure is thus suddenly removed from the surface of the lungs, which suddenly expand, and suck into their cells a quantity of air, equal to the increased dimension of the thorax.

CCCX. No sooner are the lungs thus inflated, than the muscles of inspiration begin to relax; the expansion of the intercostal muscles subjects the lungs to pressure, from the whole weight of the moving parietes of the thorax; the expanded

diaphragm is, at the same moment, made to recoil upon the lungs, by the pressure of the atmosphere on the parietes of the abdomen. By this combined pressure on the lungs, the air is again expelled.

CCCXI. Mayow compares the motion of the lungs and the thoracic parietes, to a bladder in the inside of a pair of bellows; the comparison would have been more apt, if the bladder contained a sponge to represent the air-cells of the lungs, as well as their expansibility.

CCCXII. The suction of the air into the lungs, is called inspiration, and its expulsion, expiration; respiration is these two processes taken collectively. Respiration is generally carried on without any effort of the will; but its frequency may, for a short period, be modified by volition.

CCCXIII. Although the diaphragm is the principle muscle of respiration, it was found wanting, by Diemerbroeck, in a subject seven years old. Respiration may again be accomplished by the diaphragm, in certain circumstances, without much, or any aid from the intercostals.

CCCXIV. Expiration, though generally almost a passive motion, may be accelerated by contracting the muscles of the abdomen and loins, which are attached to the ribs.

CCCXV. As the lungs are protected, from the pressure of the atmosphere, by the thoracic

parietes; when an opening is made into one division of the chest, the air rushes between the pulmonary and costal pleura, with a force which the expansibility of the lung occupying the wounded cavity, cannot resist, and the lung consequently collapses.

CCCXVI. Notwithstanding the collapse of one lung, respiration can continue in the remaining sound one; but if both sides of the chest are perforated, asphexia necessarily ensues. Perforation of the mediastinum, after one lung has collapsed, is attended with the same consequence.

CCCXVII. The force with which the lungs collapse, has been shown by Dr. Carson to be equal to a column of water of seven inches, in a bullock. His experiments prove, that the lungs must be always subject to a mechanical distending force, while the cavity of the thorax is entire.

CCCXVIII. Haller concedes a contractile power to the bronchi and air-cells of the lungs; and argues, that it co-operates in the expulsion of the air in expiration. Asthma is an irresistible proof of the existence of such a power in the lungs; but it also demonstrates, that a contractile power, so far from facilitating respiration, is a serious impediment to it. Contraction of the air-cells would, obviously, oppose the admission of air into the lungs, and prevent them from expanding, when the muscles of inspiration enlarge the cavity of the thorax.

CCCXIX. In a healthy state, the lungs are supple and pliant, and follow the movements of the parietes of the thorax, the moment they enlarge this cavity. In expiration, they are pressed by the parietes of the thorax, because the quantity and rapidity of expiration depends on the capacity of the thoracic cavity; the lungs are at the same moment relieved from the strain of distention.

CCCXX. In those cases where adhesion has taken place between the pulmonary and costal pleura, it is conceivable that the thorax may be perforated in any part of the adhesion, without collapse of the lung of the same side. It is only in cases of adhesion, I apprehend, that protrusion of a lung, through a wound of the thorax, can occur, which some authors say they have seen.

CCCXXI. When an opening is made in the chest of a dog, the air makes considerable noise while rushing into this cavity; and when the diaphragm recoils upon the lungs, part of the air is again expelled with a sound like a sudden puff of air from the nozle of a pair of bellows.

CCCXXII. Collections of air, either between the pleura or under the cellular membrane, are reduced by some vital process; but whether by absorption, as alleged by professor Chaussier, or by exhalation, or by a combination of both methods, does not seem clearly established.

cccxxiii. During inspiration, a certain proportion of pressure must be removed from the periphery of the pulmonary arteries, by the inflation of the lungs; it may therefore be presumed, that the motion of the blood in them should then be freer than during expiration. This conclusion is disputed by Bichat: "I have proved," says he, "that the state of fulness or emptiness of the stomach, and of all the hollow organs in general, brings no apparent change into their circulation; that, consequently, the blood passes through the vessels folded on themselves, as when they are distended in every sense." The same author asserts, that by exhausting the air from the lungs of a dog, and opening the carotid artery at the same moment, the blood flows as freely as when the lungs continue their function. Collections of fluids in the thorax, have again and again been urged in support of the same opinion.

cccxxiv. But these objections, it may be urged, are none of them very conclusive. It does not appear certain, that an accurate estimate of the circulation of the lungs can be formed, by gauging with the eye the jets of blood from the carotid artery. It is not true, that the expansion of hollow organs have no influence on their arteries. The pudic artery is materially affected by the expansion of the penis; the arteries of the womb, also,

are greatly enlarged in gestation; and Broussais maintains, that the stomach is in the lowest state of inflammation during digestion. The expansion of the arteries, in these organs, in the above circumstances, is in part due to the vital force; but in part also it seems attributable to mechanical distention, and removal of incumbent pressure.

cccxxv. As to the collections of fluid in the thorax, they seldom occur in both its divisions at once, to any great extent, without causing death; and one lung is capable of performing the function of respiration. In such a case, I once found the pulse even fuller and stronger than natural; but who would imagine, from this circumstance, that the lung which was consumed, had been of no use while it remained entire?

cccxxvi. But what is the effect of expansion of the lungs at birth? In the fœtus, the lungs are collapsed into very small dimensions; and the blood, instead of passing wholly along the pulmonary artery, passes in great part into the aorta, by the ductus arteriosus; but no sooner do the lungs expand after birth, than blood ceases to flow by the ductus arteriosus, and rushes entirely along the branches of the pulmonary artery. It seems to me, that cause and effect cannot be more closely allied, than this new direction of the blood from expansion of the lungs.

cccxxvii. Again, in those countries where it is customary to treat hemiplegia with emetics, paralysis of the sound side is often brought on by the long and violent expirations of vomiting.

cccxxviii. Some of Bichat's experiments would incline us to believe, that the motion of the blood in the pulmonary veins, is accelerated by expiration; I have met some proofs corroborative of this idea, but as yet I have not entirely satisfied myself of their accuracy.

cccxxix. The entrance of the blood into the pulmonary air-cells, produces a peculiar rushing sound, singularly varied by age and disease; on the difference of this sound during inspiration and speaking, Laennec has contrived to extend greatly our knowledge of the morbid changes which occur in all the thoracic viscera.

cccxxx. The thorax, when struck with the tops of the fingers, emits a hollow sound, subject also to variation by disease, from which useful information may be derived, when the Stethoscope is not at hand, in the manner pointed out by Auenbrugger and Corvisart. But diagnosis of the chest, by percussion, will most probably give place to the more certain method of exploration, by mediate auscultation.

cccxxxi. The chemical changes which result from the inflation of the lungs, is a subject of greater intricacy than the mechanism of respira-

tion, partly from natural difficulties, and partly from the theories with which it is beset. I shall consider the facts, the theories are of minor consequence.

CCCXXXII. The atmosphere is a gaseous compound of about twenty-one parts of oxygen, seventy-eight of azote, and one of carbonic acid. It is transparent and colourless, and envelopes the globe in a stratum computed at about forty-five miles.

CCCXXXIII. The weight of the atmosphere varies according to the state of the weather, and the height at which the barometrical estimate is taken; at the level of the sea, the pressure of the air raises a column of mercury about thirty inches in vacuo.

CCCXXXIV. Above the temperature of 60°, every degree of heat, according to Sir G. Shuckburgh, increases the volume of atmospheric air $\frac{1}{82}$ part; the expansion is, however, probably much above this valuation, as it is rated higher by several French Chemists.

CCCXXXV. Of the air received into the lungs, the azote is expired unaltered, and the oxygen is converted into carbonic acid.

CCCXXXVI. When any given quantity of oxygen combines with carbon, the volume of gas is not changed, but its weight is increased one-half by the addition of the carbon. The quantity of

carbonic acid expired, is therefore equal to that of the oxygen inspired, as Messrs. Allen and Pepys have proved in the Philosophical Transactions of London.

CCCXXXVII. The belief, that air is absorbed in the lungs, is of great antiquity, and was maintained also by Mayow, Willis, Borelli, and a crowd of others. Priestley and Lavoisier advocated successively the absorption of oxygen by the blood; but this assumption rests on no better evidence than the then imperfect analysis of carbonic acid, whose composition Lavoisier estimated at seventy-two of oxygen, and twenty-eight of carbon; but which later chemists value at two of oxygen, and one of carbon by weight; or, to speak in the present language of chemistry, one atom of carbon is combined with two of oxygen.

CCCXXXVIII. The surplus of oxygen which Lavoisier's analysis of respired air gave, he supposed was partly absorbed by the blood, and the remainder combined with hydrogen, to form water.

CCCXXXIX. Most fluids contain a greater or less quantity of the atmospheric gases, and there is not a doubt that the blood always contains some carbonic acid; but of what has been called oxygenation of the blood, there is no valid proof; it is, on the contrary, refuted by direct experiment.

CCCXL. Air expired from the lungs, contains the same proportional quantity of oxygen as before inspiration; this being the case, in what does the absorption of oxygen consist?

CCCXLI. Again, by agitation of venous blood in a bottle containing atmospheric air or oxygen gas, the blood assumes its bright arterial hue, the oxygen is changed into carbonic acid, but the volume of air remains the same, at least I have never been able to observe the slightest diminution of air; and I have often repeated this experiment. The chemical results, and the coloration of the blood, being in every respect the same as in respiration, is it sound reasoning to ascribe to the blood the power of absorption, while it is contained in the veins, which power is lost when it is abstracted from them. Abernethy has even maintained, that expired air is increased in volume.

CCCXLII. The absorption of oxygen was intended to explain the generation of animal heat; but as it has failed in this, it will be as well to reject a theory contradicted by many facts, and supported by none.

CCCXLIII. The obvious and principal effect of respiration, is to abstract the carbon contained in the venous blood, in its passage through the capillaries of the lungs; the blood is therefore decarbonized by respiration, and not oxygenized, as the pneumatic physiologists have asserted.

CCCXLIV. The quantity of carbon thus taken from the blood of an ordinary-sized man, is computed, by Lavoisier, at thirteen ounces in twenty-four hours. This, like all other physiological calculations, is varied by incidental circumstances.

CCCXLV. The manner in which the oxygen of the air, and the carbon of the blood, come within the sphere of each other's attraction, is still very imperfectly understood. It is, however, altogether a chemical process, quite independent of the vital force; for the coloration and decarbonization of the blood of a strangulated animal may easily be effected by forcible inflation of the lungs; this important fact is due to Lower.

CCCXLVI. The combination of oxygen with the carbon of the blood, not producing the same elevation of temperature which results from it in all other circumstances, is one of the strongest anomalies in chemistry. The physical arrangement of the integral particles of carbon, strangely influences its chemical properties; how different the combination of oxygen with the diamond, compared with the carbon of the blood.

CCCXLVII. Analogy and induction would, *a priori*, lead us to expect an elevation of temperature in the lungs, which is, on the other hand, refuted by facts; and where analogy and facts are at issue, the latter demand decided preference.

CCCXLVIII. Having already pointed out the real source of animal heat, it is unnecessary to resume the subject here; but judging solely from facts, I have no hesitation to coincide entirely with the opinion of Aristotle: *calorem de respirationegigni, persimile figmento est.*

CCCXLIX. The weight of the atmosphere so far affects the expansibility of the lungs, that the freedom of breathing is often sensibly influenced by the changes of the weather.

CCCL. Travellers who have ascended high mountains, have always found their difficulty of breathing to increase as the weight of the atmosphere diminished. Perhaps the difficulty of breathing experienced by Moorcroft and Webb, on the Hymalaya mountains, as mentioned by the Quarterly Review of 1820, may be opposed to this position; but, from the animals of these elevated regions being affected in the same manner as men, there is every reason to suspect, that the difficulty experienced by these travellers, was chiefly due to the rarity of the atmosphere.

CCCLI. Besides carbon, respiration carries off from the lungs a quantity of water in the state of vapour, in which some traces of hydrogen have been detected. Sanctorius rated pulmonary exhalation at about half a pound in twenty-four hours, Hales at twenty ounces, Abernethy at nine ounces, and some of the experiments of

Lavoisier and Seguin make it amount to two pounds; such discrepancies must invariably exist in physiological quantities; and on this head I shall once for all, transcribe the opinion of Bichat: "To calculate with Borelli the power of a muscle, with Keil the swiftness of the blood, with Jurine and Lavoisier the quantity of air entering the lungs, is to build on a quicksand an edifice solid in itself, but which shortly falls for want of a stable foundation."—*Bichat sur la Vie et la Mort*, 76.

CCCLII. While the circulation continues in warm-blooded animals, respiration cannot be long interrupted without extreme agony and imminent danger; when the venous blood passes into the left ventricle of the heart, without giving off its carbon by the air-cells, and is distributed to the other organs, the action of the nervous system is speedily affected, and muscular spasm and death ensue. This property of producing spasm, possessed by the carbon of the venous blood, seems to be instrumental in dilatation of the chest.

CCCLIII. When the venous blood enters the capillaries of the lungs, its carbon makes the muscles of inspiration contract; the air is sucked into the cells, the carbon assumes an aëriform state in combining with oxygen, and the muscles of inspiration immediately expand on the removal of the cause of their contraction. The connexion of

the phrenic and great sympathetic nerves with those of the neck, accounts for the contraction of the muscles of the neck, when deep inspirations are required.

CCCLIV. The extent of dilatation of the chest corresponds always with the quantity of carbon in the blood. After long fasting, the breathing becomes short, and the inspirations small; but after eating, the breathing is quick, and the inspirations deep. In the cold-blooded animals which pass the winter in a torpid state, their respiration is then often imperceptible, adapting itself to the scantiness of carbon in their blood.

CCCLV. The quicker the venous blood arrives at the lungs, the quicker are the inspirations. In inflammatory fevers, when the blood abounds with carbon, and the circulation is quick, the number and depth of the inspirations are always augmented. This physiological phenomenon is so obvious, as to have attracted the notice of the poet, and enters into his description of a sick warrior:

> "His blood was fever'd, his breathing was deep."

CCCLVI. When the entrance of the air into the pulmonary cells is impeded, either by division of the par vagum, or pressure upon the trachea, violent contraction of the muscles of inspiration is equally produced. In whatever light the

carbon of the blood is viewed, it appears the cause of dilating the thorax.

CCCLVII. The irritation of one part often produces muscular contraction in organs at a distance from it; thus, vomiting arises from tickling the fauces, and sneezing from sternutatories applied to the nostrils; in these cases, the sympathy is more remote than between the pulmonary capillaries and the muscles of inspiration.

CCCLVIII. Physiologists have been much at a loss to account for the first inspiration; Haller explained it rather in an odd manner. He says, that the fœtus being accustomed to swallow the liquor amni during gestation, makes an effort to continue swallowing it after birth; but, in place of this fluid, air gets into its mouth, rushes down the trachea, and inflates the lungs.

CCCLIX. If this extravagant hypothesis came from any ordinary individual, it might be left to its own absurdity; but, coming from Haller, it deserves refutation.

CCCLX. The fœtus is not nourished in utero by the intestinal canal; for if it were, the liquor amni would necessarily be mingled with excrement. Monsters of various descriptions arrive at the maturity of an ordinary fœtus, without the possibility of swallowing the liquor amni, or evacuation by the anus.

CCCLXI. Harvey thought that the blood ceasing to flow by the ductus arteriosus, was the cause of inspiration; this idea is to take the effect for the cause.

CCCLXII. Dr. Bostock seems to have had more philosophical notions regarding the first inspiration. In utero, the fœtus is rolled up on itself, and the lungs are collapsed, but quite ready to expand when the incumbent pressure is removed. The pressure of the ribs upon the lung, is partly removed by the uncoiling of the fœtus after birth; the diaphragm, in place of being pushed upon them by the abdominal viscera, is relieved, in some degree, from this force, by the body of the infant being placed in a straight position; a partial expansion of the lungs, and the removal of pressure from them, is, of course, synchronous. But, excepting this uncoiling of the fœtus at birth, I can perceive no difference between the cause of the first inspiration and any other. Whenever the placenta is separated from the uterus, or the umbilical cord tied, why should not the venous blood of an infant operate on the muscles of inspiration in the same manner as in the adult? If the uncoiling of the fœtus account fully for the first inspiration, why are the lungs of still-born infants not partially inflated by the developement of birth?

SECTION XVIII.

Irritability of the Alimentary Canal.

CCCLXIII. Besides the expansibility derived from the vital force, all the soft fibrous texture is capable of more or less mechanical extension. The coats of the intestines, which are comparatively contracted when empty, undergo great distention by repletion; but it is not to be forgotten, that while they are thus mechanically distended, they are, at the same time, pervaded by the vital force. As the alimentary canal is in constant contact with extraneous bodies, which it has to decompose for the support of the other organs, its irritability is liable to great variation.

CCCLXIV. When the repletion of the stomach is moderate, the alimentary mass causes an infinity of contractile movements in its coats; and as it is decomposed, it is forced successively along the intestinal tube, in a manner nearly similar to the motion of the lymph in the absorbents, excepting, perhaps, the power of suction possessed by the latter. But if the repletion of the stomach

be carried too far, the mere quantity of the alimentary mass produces violent spasms of the stomach, till the greater part be rejected. The quality of the ingesta has often the same effects. From these circumstances, the intestinal canal is more subject to spasms than any other organ in the human body.

CCCLXV. Vomiting may, however, be caused by a sudden afflux of blood to the cavities, even when repletion is moderate, the quality of the food wholesome, and the individual healthy; of this fact, the following is an instance. Shortly after dinner, a young Officer of the cavalry, leaped from a becalmed transport into the sea, and swam with great vivacity for a few minutes. Before he got out of the water, he was taken ill, and regained the gang-way with much difficulty. When the stomach had rejected its contents, he felt no further ailment. In this case, a sudden contraction of the extreme vessels by cold, made the blood accumulate in the cavities, and spasms of the stomach arose from the presence of a considerable quantity of food, and an unusual proportion of blood.

CCCLXVI. Sydenham and Cullen attributed vomiting in fever, to a sympathy between the stomach and the skin. The spasm, or contraction of these organs, is doubtless the same, but its causes are somewhat modified. In the cold stage

of an intermittent, the skin contracts, owing to the direct reducement of the vital force; but the spasms of the stomach arise from the blood collecting in such quantity as to impair the function of the nerves of the stomach, and thereby to suspend the generation of the expansive vital force in this organ. All the benefit arising from fomentations, in spasm of the stomach, consists in equalizing the distribution of the blood, by diverting it towards its surface, The vomiting in cholera of India, is exactly the same as vomiting in the cold stage of an intermittent, and is also relieved like it, when the natural distribution of the blood is restored.

CCCLXVII. Thus, the nerves of the stomach cannot continue their functions when they are overloaded, even by a substance which in moderation is indispensably requisite to keep up their action. But the same thing happens in the other parts of the nervous system. The optic nerve is excited by a moderate light; which may, however, be applied strongly enough to impair or destroy its faculty of vision. Deafness, too, may arise from exposing the auditory nerve to loud sounds. It is the quantity, rather than the quality, of stimulants, which in general thus renders them alternatively capable of augmenting or reducing the vital force.

CCCLXVIII. The stomach, besides being liable to spasm from changes in the distribution of the blood, is still more obnoxious to it from the contact of foreign bodies with its internal surface. All fermented liquors, in moderate quantities, raise the nervous action of the stomach; but let them be taken to excess, and vomiting follows. Change of temperature has often considerable effect in producing contraction of the stomach after drinking, by the contraction of the extreme vessels occasioning a sudden determination of blood to the cavities.

CCCLXIX. When the vitality of the stomach is morbidly increased, as in fever, or inflammation of its coats, even the presence of ordinary aliment, or the blandest liquid, convulses the stomach, which becomes quiet after the expulsion of its contents. In such a state of the stomach, its contractions should not be referred to an augmentation of the expansive vital force, but to a contractile power, generated from the contact of a foreign body with the inflamed organ; for if these convulsive motions of the stomach proceeded from mere increased vitality, then there would not be those long intermissions of vomiting which constantly occur when the stomach has evacuated its contents, however violent the inflammation may be.

CCCLXX. M. Magendie recently endeavoured to prove, that vomiting is not owing to contraction of the stomach, but of the diaphragm and abdominal muscles; if this conclusion were established, it would place the action of the stomach quite at variance with the motion of all the other soft fibres; but Maingault has shown it to be a mistake. After removing the diaphragm and abdominal muscles, he made the stomach eject its contents, by injecting a solution of the Tartrate of Antimony and Potass into the veins. In the action of vomiting, however, the abdominal muscles and diaphragm are commonly convulsed at the same time with the stomach.

CCCLXXI. The contractile vital force seems to be the same, whether it be communicated to the muscular fibres by the blood, volition, or inorganized substances; whenever they come under its influence, their expansive vital force is not only neutralized, but they are instantly corrugated, and continue so till the contractile vital force is in its turn neutralized, when they again expand.

CCCLXXII. In this inflamed state of the stomach, stimulating substances are extremely injurious; it ought not, therefore, to be confounded with the convulsions of this organ, proceeding from diminished vitality, which are frequently distant indications of death, and urgently require stimu-

lants, to renew the functions of the nerves. The first of these states happens most commonly at the beginning of diseases, the second towards their close.

CCCLXXIII. The slight healthy contractions of the intestinal canal, are called its peristaltic motion, which continues for a considerable time after death.

CCCLXXIV. The intestinal tube is more tenacious of its irritability than the muscles. This may be observed, by killing a rabbit half an hour after it has eaten food, and opening the abdomen, when the motion of the intestines may be seen to great advantage.

CCCLXXV. The nerves of the stomach are derived from the eighth pair and the great sympathetic; division of the eighth pair is followed by convulsion of the stomach, which rejects any fresh aliment as violently as if it were inflamed. Is there any difference in the cause of convulsion of the stomach, in inflammation and after the division of the eighth pair of nerves? Will any one allege, that the convulsion of the stomach, in a state of inflammation, is owing to the irritabilis naturæ of Haller, and after the division of the eighth pair to the vis nervosa? An answer to these questions, whether in the positive or negative, would equally overturn the whole fabric of Haller's irritability; or, at least, show its pal-

pable inconsistency, and the inaccuracy of separating irritability from the nervous power.

CCCLXXVI. In violent deaths, when the alimentary canal is full, some fæces are generally expelled either immediately before or after the last moments of vitality. The sudden reduction of the expansive vital force, readily accounts for this circumstance, which is common to the human species and the lower animals.

CCCLXXVII. The intestinal canal, while alive, is always moderately expanded, and does not reach its maximum of contraction till a long time after death. The stomach of a dog, even when cut from all connexion with the body, immediately after strangulation, continues contracting more and more for a full half hour. Is contraction, in such circumstances, the mere gradual extinction of the expansive vital force? This protracted contraction of the alimentary tube, accounts for the evacuation of fæces, which sometimes occurs many hours after death.

CCCLXXVIII. Bichat supposed the great sympathetic nerve, and its ganglions, to be a distinct nervous system; and partly on this hypothesis he divided the Animal Economy into Organic and Animal Life. It is, indeed, astonishing to observe how well the pectoral and abdominal viscera execute their functions in apoplexy, notwithstanding the serious injury sustained by the brain. That the

intestinal canal, the brain, and all the cerebral nerves reciprocally influence each other; no one can deny this position, except those who have confined their studies to the dead body. Emotions of the mind have powerful influence on the intestinal irritability; severe grief is frequently the cause of violent diarrhœa, and the effects of fear have not even escaped the notice of the populace.

CCCLXXIX. The irritability of the intestinal canal is generally involuntary; the task which it has to accomplish is too important to be intrusted to the caprices of volition, and its functions proceed without interruption, while the mental faculties are suspended by repose. In some few individuals there is a trifling degree of voluntary contraction in the stomach; but, in the course of my life, I have only met with one person who could at pleasure eject the contents of his stomach. Even the sight and smell of disagreeable objects sometimes convulse the stomach.

CCCLXXX. A morbid state of the intestinal canal readily influences the brain; the presence of worms in any part of it, and acrid or corrosive poisons, readily induce delirium and coma; and even excessive repletion may bring on a state resembling ebriety. The inhabitants of Australia, whose subsistence is extremely precarious, commit enormous excesses of gluttony, if plenty be within their reach. When a whale is accidentally

thrown ashore, the news is instantly communicated to the adjacent hordes, who assemble from all quarters to riot on the blubber, till they become in some degree delirious.

CCCLXXXI. Repletion impedes respiration, by preventing the descent of the diaphragm.

CCCLXXXII. Much has been written on the sympathy between the intestinal canal and the dermoid system; and though I am not prepared to deny altogether this mutual influence of the central and peripheral surfaces of the human body, yet it exists most between the intestines and the extreme vessels, with which every viscus has a direct sympathy.

CCCLXXXIII. The blood performs offices so important in the animal economy, that any considerable variation in its quantity, operates on the irritability of the organ in which it occurs. In temperate and cold climates the blood abounds in the viscera, and there the irritability of the intestines is brisk, and the evacuations free; but in tropical countries, the blood is most abundant in the extreme vessels, the contraction of the alimentary tube is feeble, and the evacuations scanty. There are consequently sound physiological reasons for the inhabitants of hot climates resorting to the use of aromatic spices, curries, and other highly-seasoned aliment, to excite a slight determination of blood to the intestines, and to

support their contraction in a salubrious state. Besides spicy aliment, the Asiatic Indians chew the nut of the Mimosa Catechu, and the leaves of the Piper Betel powdered with chalk, which keep up the salutary action of the bowels. But spices, which are beneficial in the torrid zone, are for the most part injurious or superfluous in cold countries, where the distribution of the blood is adequate to maintain the healthy irritability of the bowels.

CCCLXXXIV. Before quitting this subject, it may not be irrelevant to notice the manner in which the alimentary canal is closed at its termination.

CCCLXXXV. The end of the rectum is surrounded by numerous spongy fibres, interwoven with each other, which in a healthy state are always in a state of expansion that is only overcome by mechanical force: by this mechanism, the rectum is firmly and constantly shut, and the egress of fæcal matter prevented. When the pressure of the fæces is on the point of overcoming the expansibility of this spongy texture, it becomes necessary either to expel them, or to contract the sphincter and levator ani, which are completely at the command of the will. The expansibility of this fibrous tissue is sometimes destroyed in hemiplegia, and when this is the case, it forms a most distressing part of the disease.

SECTION XIX.

Digestion.

CCCLXXXVI. By digestion, is understood the transmutation of substances in the alimentary canal, and their separation into chyle and fæces. The diversity of thinking, and the discrepancy of facts which prevail on this important part of physiology, invite to further inquiry and experiment, to extricate it from the doubt and obscurity in which it is involved.

CCCLXXXVII. Hippocrates, and the ancients in general, considered digestion a sort of coction or boiling of the food; heat, according to this doctrine, is the primary agent of alimentary decomposition, and without it, Aristotle asserts that no solution can be effected: the sentence in which this idea is expressed is worthy of quotation, from the sound physiological notions which it conveys: "Non enim concoctio, sine anima et calore absolvi potest."

CCCLXXXVIII. Pringle and Macbride contended, that digestion is an operation of the particles of

the ingesta upon each other, like fermentation. In their time, chemistry was in its infancy, and fermentation little understood, but this opinion was refuted by facts of which they were even in possession. Digestion is usually accomplished in four or five hours; fermentation, whether vinous, acetous, or putrefactive, requires days, even in the most favourable circumstances; and its products are either alcoholic and acid fluids, or carbonic acid gas, substances not very liable to be confounded with chyle and fæces.

CCCLXXXIX. Other physiologists referred digestion to the mechanical friction of the parietes of the stomach on the alimentary mass. The arguments in favour of this theory were chiefly drawn from observing the power with which the gizzards of gallinaceous birds pulverize hard substances. The trituration of birds gizzards is, more properly speaking, mastication than digestion of aliment, for no modification of mechanical force can convert it into chyle.

CCCXC. In 1752, Reaumeur published two papers in the Memoirs of the Royal Academy of Paris, which introduced new and sounder views of the digestive process. He put pieces of flesh into tubes open at both ends, for the purpose of admitting the free access of the gastric juice: birds of prey were forced to swallow the tubes thus prepared; and the pieces of flesh having in

all his experiments undergone some dissolution, he conceived that this change had been effected by the solvent power of the gastric fluid. He made similar experiments on birds with gizzards, but in place of the pieces of flesh he substituted grain, which was also more or less dissolved in its passage through the intestinal canal. The solution of the grain, in the latter set of experiments, corresponding with the solution of the flesh in the first, confirmed him in the opinion that the gastric juice was the chief agent of decomposition in both.

CCCXCI. But if the gastric juice be so active a solvent in the stomach, it was reasonable to infer, that it would also dissolve the same substances out of the body, when aided with heat; and to effect this kind of solution, Reaumeur made two attempts, but met with a complete failure in both instances. It was from his experiments that Haller concluded, that the gastric juice, even with the assistance of heat, does not digest out of the body.

CCCXCII. After the two memoirs of Reaumeur, came that of Mr. Hunter, in the Philosophical Transactions of London for 1772. In some instances of sudden death, he had found parts of the stomach in a half dissolved state, which he supposed to have been occasioned by the gastric juice operating on the stomach itself after

death. This solution of substance he represents as not confined to the stomach, but extending to the contiguous viscera, and corroding even the diaphragm itself. Mr. Hunter's acuteness of observation, and fidelity of description, are worthy of every credit; but that these morbid decompositions are the effects of the gastric juice, is highly improbable, as it is found to possess no such active properties, when procured even in its purest state. But on this subject, some observations will be offered in the sequel.

CCCXCIII. The Abbé Spallanzani repeated the experiments of Reaumeur, and varied his method of artificial digestion, which was attended with rather more success than that of his predecessor. The two following experiments are extracted from the Abbé's elaborate work, and seem the most favourable to the theory which he advocates.

CCCXCIV. " I exposed to the sun two phials filled to a certain height with gastric juice from crows, in one of which were immersed several pieces of beef, and in the other crumbs of wheaten bread. Nine hours of sunshine much forwarded the artificial digestion, which was the object of my inquiry A good part of the flesh was reduced to a kind of glue, which adhered to the fingers when handled: nothing like flesh remained in any of the pieces but the nuclei, which were still con-

sistent and fibrous, which two qualities they lost next day. After having been exposed to the sun six hours, the nuclei, like the outside, no longer retained a fibrous structure. In the sun, the heat, as well on the first as the second day, was between 122° and 133° of Fahrenheit's thermometer. The gastric juice had produced upon the bread a change analogous to that which the flesh had undergone. It had not only lost its white colour, but had become viscous, and no longer presented to the eye the appearance of bread. Of bread, as well as flesh, immersed in water, exposed to the sun for some time, there was a perceptible diminution, but it was inconsiderable when compared with that produced by the gastric juice." p. 95.

cccxcv. "I took two tubes, sealed hermetically at one end, and at the other with wax; into one I put several bits of mutton, and into the other several bruised grains of wheat, and then filled them with gastric liquor; and as the warmth of the stomach is probably another condition necessary to the solution of food, I contrived to supply it by fixing the tubes under my axilla. In this situation I kept them at different intervals for three days, at the expiration of which I opened them. The tube with the grains of wheat was first examined; most of them now consisted of bare husk, the flour being extracted, and forming

a thick grey sediment. The flesh in the other tube was in a great measure dissolved, and was incorporated with the gastric juice, which had become more turbid and dense. What little remained had lost its redness, and was now exceedingly tender. Upon putting it into fresh gastric liquor, the remainder was dissolved in the course of a day." p. 57.

CCCXCVI. These are the strongest proofs which Spallanzani has been able to adduce in favour of solution by the gastric juice out of the body, and let them be contrasted with the facts known in healthy digestion. A period varying from four to six hours, completes the digestion of an ordinary meal; four days, with a change of gastric juice, are required to effect the solution of a few pieces of mutton out of the body. The gastric juice being the same in both cases, the difference in the rapidity of solution must therefore depend on the receptacle, and not on the solvent. If the aggregate of the Abbé's experiments be taken exactly as they are related by him, they prove no more than that the gastric juice is a very feeble agent in the process of digestion, and some of them would lead to the belief that it has no solvent power greater than water.

CCCXCVII. "Having prepared," says he, "several glass tubes of the length of six inches, I sealed them hermetically at one end, and the opposite

extremities were drawn out so as to form elongated cones; through the open ends of these cones I poured a quantity of gastric fluid, together with a few pieces of flesh. I then introduced the cones by the bases, into the stomach of some crows, allotting one to each bird; and when they rested upon the bottom of the stomachs, their apexes came out at their mouths. The flesh remained several hours immersed in the gastric fluid without showing any sign of decomposition." But "when the cones were kept ten or twelve hours in the stomachs, the flesh was generally reduced to a coloured gelatinous pulp." p. 99.

CCCXCVIII. The late Dr. Montegre, who possessed the faculty of vomiting voluntarily, made, some years back, repeated experiments on his own gastric juice, vomited in the morning before breakfast; but all his efforts to dissolve food in it proving abortive; he alleged that the gastric juice is only a bland diluent like saliva, and is destitute of the active solvent properties ascribed to it by Hunter and Spallanzani. These opinions were submitted in a memoir to the Royal Academy, and were favourably received by that learned body. Professor Thenard also leans towards the same way of thinking, in his public Lectures on Chemistry, in the College of France.

CCCXCIX. Some very eminent physiologists before Montegre, have set little value on the decom-

posing power of the gastric juice. Dr. Fordyce states, that " digestion is performed on substances containing all the elements of chyle. The substances in the stomach, and other organs of digestion, have the elements separated from one another by the effects of the stomach, and other organs of digestion upon them, occasioning in them a decomposition, and a recombination of their elements into a new substance." Nor is the stomach the only part of body in which decomposition occurs. Helvetius states, that flesh and fish have been found half decomposed in the gullets of birds; and the late Dr. Curry, of this place, kept a gentleman alive from the 17th of October to the 6th of December, by nutritive injection. In this last instance, digestion must undoubtedly have been effected in the colon and rectum.

CCCC. Assimilation, secretion, suppuration, and the decay of organs, also evidently evince that the vital force is possessed both of dissolving and recomposing properties; and supposing it to be a modification of Galvanism, arising from the contact of the nerves and blood-vessels, it appears not unfeasible that a decomposing power might be shown to exist in every part of the animal economy. With these reasonings in view, Dr. Sillar and I undertook the following experiments, which were published in the London Medical and Physical Journal of last March.

CCCCI. 1st. A piece of roasted mutton slightly powdered with salt, was put into the rectum of a dog. It was extracted at the expiration of eleven hours, and was found changed on the whole of the outside, into a whitish-brown saponaceous paste. A small part of the centre retained its fibrous appearance.

CCCCII. 2nd. Two pieces of roasted veal were introduced into the rectum of the same dog, one of which was inclosed in a single fold of muslin. They were allowed to remain sixteen hours; the piece without the muslin was pulverulent externally, and seemed only to require the aid of moisture to have the appearance of paste; its centre was unaltered. The veal contained in the muslin exhibited nearly the same appearance, but its pulverulence did not extend so far towards the centre as in the other piece. This experiment succeeded less perfectly than the first; a thick layer of fæces coated the veal, and doubtless sheltered it from the moisture and vital action of the rectum.

CCCCIII. We repeated the first experiment, using veal instead of mutton; and the result being the same, it is unnecessary to detail it.

CCCCIV. 3rd. A dog that had fasted twelve hours was killed; two drachms of gastric juice were obtained from the stomach, and poured into a small oval phial, containing a cylinder of boiled

beef, weighing five grains. The mouth of the phial was closed with a ground stopper, firmly secured by a silver top screwed upon it; and to apply a proper degree of heat to the contents of the phial, it was placed in the rectum of another dog, where it remained eleven hours. About three-quarters of the beef were dissolved; the remainder was black and viscous. Before putting it into the phial, it had a thread wrapt round it, for the purpose of facilitating its extraction when the experiment should be finished, the parts of the beef in contact with the thread not being so much dissolved as the remaining surface, which was freely exposed to the gastric juice; the remainder of the beef had an angular appearance. Although we were not prepared to expect this result from our experiment, yet it left no doubt on our minds, that the gastric juice, when obtained pure, is slightly solvent, even out of the body, if the artificial digestion be conducted with the necessary precautions.

CCCCV. We repeated the last experiment, but in place of gastric juice, the phial was half filled with saliva. The piece of beef which was put into it, had undergone no perceptible change, but its smell was become very offensive.

CCCCVI. We tried to digest boiled beef in gastric juice, in a temperature varying from 50° to 60° of Fahrenheit, but no decomposition was

effected. The beef, however, had no unpleasant smell, which shows that the gastric juice is more antiseptic than saliva. The gastric juice obtained by swallowing sponge, or exciting vomiting, can never be pure, for the stomach is always lubricated with mucus and saliva, which must mingle with the gastric fluid procured by either of these methods; besides nausea is always attended with a copious discharge from the fauces and salivary glands. These sources of adulterating the gastric juice, readily explain the discordance of experiments on artificial digestion. The only way to get gastric juice fit for experiments, is to kill an animal that has been without food and drink for twelve hours. These precautions being taken, we never obtained above two drachms from one dog.

CCCCVII. 4th. An incision was made in the thigh of a dog, separating the cellular membrane from the muscles, and a slice of boiled mutton put into the wound, which was then closed with a stitch. The wound was examined at the expiration of thirteen hours; its edges had united by the first intention, so that we were obliged to employ the scalpel to get out the mutton, which was found partly decomposed and partly fibrous.

CCCCVIII. 5th. On extracting the mutton, another slice was introduced into the same wound, with the intention of allowing it to remain twenty-four hours; but at the end of seven hours,

the pulp of the mutton was observed escaping through the lips of the incision, and on examination it was discovered that the whole of the mutton was already decomposed, and changed into a soft saponaceous mass, in which no trace of fibrous texture could be detected. The difference between these two experiments was at first inexplicable, but by repeating them it appeared, that when slices of beef or mutton are put into recent wounds, adhesion is extremely apt to take place between the living and dead parts, and no decomposition is effected where adhesion is formed. But when a wound becomes considerably inflamed, no adhesion ensues, and the decomposition of the dead parts by the living is more rapid.

CCCCIX. 6th. A slice of raw flesh was allowed to remain twelve hours in a wound, the side applied to the muscles of the dog was covered with a stratum of pulp; the whole had a parboiled appearance, and was very tender.

CCCCX. The slices of meat put into the wounds weighed from fifteen to twenty grains, and the decomposition appeared generally most successful when it was cut in the direction of its fibres. The boiled meat was found to adhere more readily to living muscles than the raw; a circumstance which, *à priori*, would appear unlikely.

CCCCXI. The third experiment does not permit denying that the gastric juice exercises a slight

solvent power; but at the same time it authorizes the conclusion, that its agency is only of secondary importance in the decomposition of aliment in the stomach. No more solvent influence can justly be ascribed to it in digestion, than what it possesses out of the body. In the space of eight hours, Dr. Stevens dissolved twelve grains of beef in half an ounce of gastric juice, exposed to a heat of 102°, which may be considered as the most successful instance of artificial digestion that can be accomplished. It must, therefore, be obvious, that if digestion depended solely on the gastric juice, the process would not only be tedious, but the quantity of it required, would also be enormous. As a secretion, however, it is scanty; as a solvent, it requires the co-operation of heat.

CCCCXII. As the activity of the gastric juice depends on the degree of heat to which it is exposed, all those experiments conducted in temperatures higher than the blood, cannot be applicably compared with the digestive process of the stomach.

CCCCXIII. The gastric juice is neither acid nor alkaline in carnivorous animals, but some trace of an acid may usually be detected in that of the graminivorous animals. When an acid abounds in the human stomach, it is the product of disease, and the digestion is then always weaker than

natural; the solvent power of the gastric juice cannot therefore be owing to acidity.

CCCCXIV. When the autopsies of the intestinal canal are performed with care, nothing is more common than to find parts of its inner coat destroyed by ulcerative inflammation; but that sort of decomposition of the stomach mentioned by J. Hunter, as occurring in cases of sudden death, is extremely rare. His opinion, that this morbid appearance is caused by the gastric juice, cannot be accurate; for except in a temperature approximating that of the blood, it possesses no solvent power superior to water; and even according to Mr. Hunter's own authority, the gastric juice cannot act on a substance endowed with vitality, of which the stomach continues to be possessed for several hours after death. In this country, consequently, the vitality of the stomach must resist the operation of the gastric juice till the temperature sinks low enough to render it inactive. Spallanzani has recorded several experiments which corroborate this conclusion. The only explanation of the morbid symptoms described by Mr. Hunter which I shall offer, is the following quotation from his own work on Inflammation: "Such deaths as prevent the contraction of the muscles, or the coagulation of the blood, are, I believe, always sudden. Death from sudden gusts of passion is

of this kind, and in all these cases the body soon putrifies after death."

CCCCXV. From the two first experiments above detailed, it appears that the rectum, like the stomach, can decompose animal substances placed in contact with it, while the fourth, fifth, and sixth experiments show that the whole animal body has a similar property. The incorporation of the boiled meat with the living muscles, while the wounds were fresh and the inflammation low, is not less curious than the decomposition of the meat when the inflammation of the wound became severe. Decomposition and assimilation going forward at the same time in one place, seem at first sight rather a chimera of the imagination, than a grave and irrefragable matter of fact; but the integrity of structure is maintained solely by this power which the different organs possess, of converting the blood into a substance similar to themselves.

CCCCXVI. In phlegmon, the vital force becomes intense enough to decompose the fibrous texture of the inflamed part, and even melt down the nerves and blood vessels that disengage it.

CCCCXVII. From all these facts and arguments, it appears positive, that wherever there are nerves and blood-vessels, there also must exist a decomposing power; and that this vital force, which is the cause of assimilation, secretion, &c. in the

other parts, is the cause of the decompositions which occur in the alimentary canal.

CCCCXVIII. In the stomach, the points of contact between the nervous and vascular systems, are more numerous than in any other part of the alimentary tube; and there, too, decomposition is most rapidly effected.

CCCCXIX. Digestion is not, however, confined to simple decomposition of substances submitted to its vital force; there is likewise a re-union of the particles of the decomposed substance into a new homogeneous mass, which in its turn undergoes successive mutations. The substances decomposed, in all instances contain the ingredients of the new product, but require to have their particles differently arranged before they can be fitted for the various purposes to which they are destined. Thus, a piece of muscle may contain all the integrant particles necessary for nutrition, at least it can assimilate with living parts, but in its solid state it cannot pass into the circulating mass of fluids to excite the nervous system and supply the materials of organization.

CCCCXX. Digestion thus consists of two processes —decomposition of aliment, and chylification.

CCCCXXI. Mastication is a preparation of the aliment for digestion, by which it is mechanically comminuted by the teeth, and lubricated with saliva, of which the motion of the lower jaw,

and the taste of the food, cause an abundant secretion. Dr. Fordyce rates the quantity of saliva secreted at a meal, between one and two ounces.

CCCCXXII. Deglutition of the masticated food is effected by the tongue forcing it into the pharanx, the contraction of whose muscles impels it into the œsophagus, which is also endowed with contractibility, by which it is finally conveyed into the stomach.

CCCCXXIII. Without a considerable quantity of fluid be taken with the aliment, the sensation of thirst is urgent and disagreeable; hence most animals are disposed to drink after feeding.

CCCCXXIV. After a meal, the inner surface of the stomach is in close contact with the alimentary mass, from whose whole periphery decomposition begins, and advances towards the centre. This progressive decomposition from circumference to centre, is seen advantageously in dogs, as they take little pains to masticate their food. The decomposed aliment mingles with the drink and the gastric juice, in which it partly floats and is partly dissolved; this mixture forms the chyme, which is gently forwarded through the pylorus by the contraction of the stomach.

CCCCXXV. The pylorus is said to permit only the chyme to pass through it; and this idea seems true to a great extent, for it contracts easily on very small substances, but it is notwithstanding,

certain, that husks of beans, stones of cherries and plums, and even substances of greater magnitude, find their way through the pylorus without much difficulty.

CCCCXXVI. As the expansion of the stomach is in part caused mechanically by the alimentary mass, its central surface does not cease to be in constant contiguity with the periphery of the aliment, though its bulk lessens by decomposition.

CCCCXXVII. When, however, the quantity of food is inconsiderable, its upper surface is not in contact with the stomach, when the body is in the erect position; and owing to this natural expansion of the stomach, the duration of digestion is not in exact proportion to the quantity of aliment. Fordyce, whose treatise on digestion is the best that I have perused, gives a statement very different; he says that "the stomach is always full, whether it contains an ounce or a quart of any solid or fluid matter." On opening dogs which had fasted ten or twelve hours, I have always found their stomachs expanded sufficiently to hold about a pint of fluid, and when any part of undigested aliment remained, it never was encircled by the stomach, as represented by Fordyce, but only in contact with its surface, which happened to be lowest at the time of examination. The attachments of the stomach, and even the spleen, would oppose its contraction like the bladder or uterus. I am thus particular

in pointing out this circumstance, as the errors of a good work are the most mischievous.

CCCCXXVIII. After a hearty meal, there is generally a disposition to repose, which is not confined to the human species; most animals indulge in rest after eating, which accelerates digestion. The presence of food acts as an agreeable stimulus to the nerves of the stomach; there is a determination of blood to this organ, and here the vital force is temporarily augmented.

CCCCXXIX. Digestion proceeding more rapidly in repose, does not, however, lead to the inference, that the decomposing power of the stomach is lessened by exercise; but violent exercise disturbs that determination of blood which should follow repletion. The secretion of the gastric juice must consequently be less abundant, and the liquid part of the alimentary mass speedily absorbed, to supply the waste of fluids by cuticular and pulmonary exhalations. Thus, there is not sufficient menstruum left to liquify the pasty decomposition of the solid food, and convey it through the pylorus in a chymous state.

CCCCXXX. In the cold seasons, the determination of blood to the stomach is often such, as to bring on a thrilling sensation of cold in the extremities, which indicates a very active state of the digestive organs. In hot climates, there is no feeling of cold after eating; the expansion of the extreme

vessels retains the blood in abundance at the surface of the body, which renders digestion more tedious in tropical climates than in the temperate and frigid zones. The coarse fat aliment which is easily digested by the Greenlander, would be instantly rejected by the stomach of the Hindoo.

CCCCXXXI. All nations use condiments of some description, which give increased activity to the vital force of the stomach, and the hotter the climate the more necessary they become. They require, however, to be used with discretion, for any stimulus, however salutary, may induce debility when employed beyond proper limits.

CCCCXXXII. A moderate quantity of wine, or other alcoholic beverages, also augment the vital force of the stomach, and consequently increases its digestive power; in youth they are, however, superfluous, but in the decline of life necessary. *Nihil nimius*, is a precaution which every judicious man should observe in his enjoyments, but in none more than in his use of wine, or stimulants, of whatever description they may be.

CCCCXXXIII. The chyme is a pulpy semi-fluid mass, varying in appearance according to the nature of the aliment and drink from which it is formed. The chyme is stated to contain an acid, which circumstance might almost be presumed *à priori*, from the number of ingredients which enter into its formation.

CCCCXXXIV. The chyme, after passing the pylorus, is submitted to the vital action of the duodenum and jejunum, which separates the nutritious from the excrementitious part of the alimentary mass; the nutritious part, which is white and liquid, is called chyle; the excrementitious part is more consistent, and tinged yellow by the bile.

CCCCXXXV. It is a commonly received opinion, that the pancreatic and biliary secretion separate the chylous from the fæcal matter in the small intestines; but there is not one fact corroborative of this assertion. It is not a little curious that M. Magendie, who is generally very delicate in giving way to an hypothesis without fact, should have adopted this gratuitous conclusion, without even offering an argument in its favour. "Le mode d'alteration qu'eprouve le chyme dans l'intestin grêle est inconnu; on voit bien qu'elle résulte de l'action de la bile, du suc pancreatique, et du fluid secrété par la membrane muqueuse sur le chyme." How M. Magendie came to see that chylification is caused by the bile, the pancreatic juice, and secretion from the mucous membrane, he has given no information.

CCCCXXXVI. The bile is an acrid secretion, which supports the irritability of the intestinal tube, and enables it to propel the fæcal part of the aliment; but in a temperature of 98°, Dr. Sillar and I have not found it possessed of the least

solvent power. What the solvent powers of the pancreatic juice may be, I cannot pretend to say, but it is soon enough to believe in them when they shall be shown to exist.

CCCCXXXVII. The alimentary tube is known to possess decomposing properties, and so long as its fluids are not known to have like qualities, it is a fair logical inference to assume, that the decompositions which occur there, are effected by the tube itself, and not by the fluids contained in it. I would not argue that these secretions have no operation in chylification; I merely regard them as minor adjuments to the vital force; they appear concurring rather than essential causes of chylification.

CCCCXXXVIII. The fæcal part of the aliment becomes thicker and thicker in its progress along the intestines, as the chyle and fluids are absorbed.

CCCCXXXIX. "The chyle consists of three parts; a part which is fluid, and contained in the lacteals, but coagulates on extravasation. The second part consists of a fluid, which is coagulable by heat, and in all its properties is consonant to the serum of the blood. The third part consists of globules, which render the whole white and opaque."—FORDYCE.

CCCCXL. The chyle is no doubt influenced by the description of aliment, for the flavour and quality of animal flesh differs materially according

to the nourishment on which it is reared. Chyle from vegetables contains, according to Dr. Marcet, more carbon than chyle formed from animal substances. Chyle contains all the integrant particles of the blood.

CCCCXLI. The chyle is taken up by the lacteal absorbents, and conveyed by them into the thoracic duct, which finally empties it into the right subclavian vein. The jarring opinions respecting the capability of the lacteals to absorb other substances beside chyle, have been already noticed, and need not be repeated here. It is obvious, that if the lacteals absorbed every thing presented to their mouths, the fæcal matter which would in that case be taken into the circulation, would be productive of serious inconvenience; but that they are exclusively appropriated to absorb the chyle, is a matter still to be ascertained.

CCCCXLII. A sufficient supply of nutritive aliment is the best guarantee of health and longevity. If starvation were as salutary as hypothetical physiologists would represent, and plenty pernicious, then ought the nobility of these kingdoms to be the shortest lived individuals in it, whereas the contrary is notoriously the case. Enjoyment and health are to be found neither in fasting nor gluttony; debility and excitement are equally productive of disease.

SECTION XX.

Irritability of the Penis.

CCCCXLIII. The penis is a spongy fibrous substance, composed of the glands, urethra, and corpora cavernosa; in general it is soft and pendulous, but in erection hard and rigid. The hardness of the penis proceeds from a sudden expansion of its cavernous texture, which is at the same instant filled with blood from the pudic arteries. Expansion of the penis arises most commonly from sympathy with the brain and testicles.

CCCCXLIV. Castration has been long known to prevent the growth of the cervical muscles of male animals, but Gall was the first to detect an intimate relation between the cerebellum and the genital organs. The intensity of the venereal appetite is found to vary according to the developement of the cerebellum: when this organ is inflamed, it often causes the most distressful priapism. Even in a case where a patient had been reduced by previous disease, I have known inflammation of the cerebellum produce the most

frightful activity of the genitals, which continued till within a short period of dissolution. M. Serres, in his work on Apoplexies, mentions an interesting case of a child that died of inflamed cerebellum, of which priapism was the most remarkable symptom during the progress of the disease.

CCCCXLV. Wounds of the occiput sometimes induce impotence.

CCCCXLVI. There is no cue by which the cause of these remote sympathies can be explained; to detect their existence, is the philosophic boundary of research.

CCCCXLVIII. The expansion of the penis is caused by augmentation of its vital force; its spongy substance no sooner expands, than the pudic arteries discharge a greater quantity of blood into it; its heat is increased, the arteries throb, and the whole organ is rigidly enlarged. Erection of the penis has been ascribed to pressure upon its veins, which in fact exists, but which proceeds really from expansion of this organ itself.

SECTION XXI.

Vesical Irritability.

CCCCXLIX. The bladder is a fibrous bag, destined to receive the urine from the ureters; its capacity is considerable, which renders a frequent discharge of the urinary secretion unnecessary. Although inconsiderate theorists have brought the doctrine of final causes into contempt, there is no valid objection to them, when their purposes are obvious; how miserable would human existence be, if the urine dribbled incessantly from the urethra, as it is secreted! How carefully have our convenience and comfort been studied, in the structure and functions of all our organs.

CCCCL. The expansibility of the bladder is entirely passive; what Fordyce has said of the stomach, is strictly applicable to this organ; it is always full, whether it contains an ounce or a pint. The fibres of the bladder yield readily to the mechanical distention of the urine, but when this distention goes beyond a certain length, it produces an uneasy sensation, and desire to make water.

CCCCLI. The internal orifice of the urethra is at the side of the bladder, by which arrangement it is less subject to pressure from the urine, than if it had been placed at the lowest part of this organ. The orifice of the urethra does not appear to be closed solely by that part of the muscular coat of the bladder called the sphincter vesicæ. It is clear, that when this part of the muscular coat contracts, the fibres of which it is a continuation, should contract likewise, and expel the urine, in place of retaining it in the bladder. While the bladder is filling, its muscular coat is strained by the mechanical operation of the urine; the sphincter vesicæ must be strained by the same means, and thus probably contributes feebly to close the orifice of the urethra.

CCCCLII. The prostate gland, and the expansible tissue about the mouth of the urethra, seem to close it in the same manner as the anus. At the commencement of making water, an effort is required to overcome this expansible tissue; but when the urine has begun to flow, it keeps the orifice open to admit the following current pressed upon it by the contraction of the bladder. When the prostate gland is much enlarged, pressure upon the periphery of the bladder, and contraction of its coats, are inadequate to open the mouth of the urethra, and the urine has to be abstracted by a catheter.

CCCCLIII. When the desire of making water is urgent, contraction of the levator and sphincter ani obstruct the egress of the urine; but they seem to operate mostly upon the membranous part of the urethra.

CCCCLIV. The excitement about the orifice of the urethra, from the inconsiderate use of cantharides, occasions a difficulty of making water; and inflammation of the bladder itself, causes it to be made more frequently.

SECTION XXII.

Uterine Irritability.

CCCCLV. The uterus is the most expansible organ of the human body; in the unimpregnated state, its bulk is inconsiderable; but after conception, and the descent of the ovum into its cavity, its texture yields to the increasing size of the fœtus and placenta. The gradual enlargement of the fœtus and its appendages, is favourable to the extension of the uterine fibres, which would probably contract, if they were more speedily stretched out.

CCCCLVI. The arteries of the uterus are enlarged in size during gestation, and sometimes it is necessary to moderate their action by bleeding, to prevent premature contraction of the uterine fibres.

CCCCLVII. About nine months after conception, the uterus arrives at the utmost extent of expansion, and begins to contract upon its contents. The long intermissions between the labour pains, show that the contractile power is easily exhausted, requiring considerable time to recruit itself.

CONCLUSION.

The progress of knowledge is most commonly from effects to causes; but when any phenomenon, or series of physical facts, has been traced to its source, the power by which bodies operate on each other still remains occult and inexplicable; or, in other words, the connexion between cause and effect is unknown. To explain the operation of bodies, some have affirmed a specific interference of Divine Power in every physical consequence. This doctrine seems to have a very different tendency from what its abettors proposed. In those operations of bodies which are subject to human direction, what is the influence of human power as regarding the interference of the First Cause? This question, though of a revolting description, may be reasonably asked on the above proposition. The chronometer moves for years without requiring the finger of the horologist at the lever; and while man can effect so much, it is, at least, arrogant to specify the nature, or limit the extent to which the Deity interferes in the reciprocal operation of bodies. Every candid and enlightened man must admit his entire igno-

rance why certain effects proceed immutably from certain causes; and any attempt to explain their relation, is a search of truth in the boundless regions of possibility.

By physical consequence only, do we acquire a knowledge of power; for example, the contact of one plate of copper and another of zinc, generates galvanic electricity; but the operative power from which this phenomenon results, is unknown. There is nothing in bodies which, *à priori*, indicates their properties; a knowledge of them is obtained only by experience. I would not, however, indirectly insinuate that the properties of bodies are self-existing and inherent qualities; their operations give us an idea of power, which is irresistibly attended with the idea of a governing influence; for it is impossible to conceive force without direction, unless we can at the same time form an idea of action without agency, and arrangement without intelligence. All the phenomena of nature are indicative of unlimited wisdom and power; hence it is to be presumed, that the properties of bodies must be derived from the Cause of nature.

In the foregoing investigation of Physiological causation, I have uniformly traced Irritability and Decomposition to a power generated between the blood and nervous system. This power, I am persuaded, is either Galvanic Elec-

tricity or a modification of it; but if I am wrong, it is an error which I participate with Newton, Gaubius, Hunter, Wollaston, Abernethy, and Philip; and who need be ashamed to err with such authorities, even if the opinion itself were unsupported either by analytic or synthetic analogy? It would be satisfactory to have an incontestible proof that the Vital Force is Electric; but, if a power of regulating it can be acquired, the most important point is achieved. Every author who has considered the Animal Economy with any degree of profundity, has admitted the existence of the Vital Force, though under different appellations: Hippocrates calls it Nature; Van Helmont, Archæus, and Stahl, the Soul; Hunter, Materia Vitæ; and Cullen, the Nervous Power and Vis Medicatrix Naturæ. I have shown that the Vital Force does not proceed exclusively from the blood, or from the nerves, but results from their mutual operation on each other; and is, to a certain extent, under the Physiologist's control. It is not an *ignis fatuus*, it is a substance perceptible by the senses; it is tangible by the thermometer; it manifests itself in decomposition, and in the motions of all the soft fibres. I do not pretend to comprehend the operation by which the blood and nerves produce the Vital Force; but its phenomena are as capable of arrangement and investigation as

any other series of physical facts. The most formidable difficulties which encompass Physiology, are the multitudinous changes which the Vital Force undergoes from contingent circumstances; and to detect the nice differences of these changes, forms the essential qualification of the Physician.

Since I wrote the article on Animal Heat, I have seen a curious illustration of the relative effects of the motion of the blood and its contact with the nerves. John Lucas, aged 78, has been for some months under the treatment of Dr. Sillar and Mr. M'Donald of the Liverpool Dispensary, who had the goodness to call my attention to his peculiar case. The disease is a hypertrophy and dilatation of the left ventricle of the heart, which contracts 31 times in the minute, and the heat under the tongue is 96°. The pulse of his wife, who is 74 years old, is 70 per minute, and the heat under the tongue 98°. The difference of 39 pulsations in these aged persons, makes only a difference of two degrees in their animal heat.

The existence of a contractile power in the soft fibres of the body is universally admitted in the present state of Physiology; in the foregoing pages, I have proved, by a series of arguments and experiments, that there is also an expansive power which pervades the fibrous texture of the body. The pressure or ligature of a nerve de-

monstrates that this expansive power is essentially derived from the Nervous System; the same thing is proved by applying nitrate of silver over the course of a nerve proceeding to a paralytic limb. The expansion of the iris and the corpora cavernosa penis have thus been reconciled with the expansion of the muscular fibres. Involuntary contraction proceeds most commonly from the operation of the blood, and from all other causes which either directly or indirectly reduce the Vital Force; and if the expansive and contractile powers, which alternately operate on the fibres, be modifications of positive and negative Electricity, expansion and contraction are readily explained. The sensation of Clonic spasm resembles an Electric shock so closely, that it is impossible to distinguish the difference between the two sensations. But whatever may be the nature of the Vital Force, its expansive power being at the command of the practitioner, may be turned to practical account.

I have already stated the analogies between Galvanism and the Vital Force, which led to the experiments on the decomposition of aliment; it is, therefore, unnecessary to recapitulate these resemblances in this place. Whether, therefore, the Vital Force be considered as a power generating Caloric, or causing the compound motion of Irritability, or decomposing substances sub-

mitted to its influence, and forming their integrant particles into bodies possessing new properties, its affinity to Electricity is closely exemplified; and the period is probably not far remote, when Newton will deserve as much credit for his conjectures on vitality, as on the combustibility of water and the diamond.

APPENDIX.

Practical Observations.

Agues.—I shall not stop to inquire here how far the practice of Medicine and Surgery should be guided by Physiology, but shall content myself with showing in what circumstances a few obstinate disorders may be advantageously combated, on the physiological principles which have been propounded in these pages. The stretching and coldness of the extremities, and the contraction of the extreme vessels which usher in a paroxysm of Intermittent Fever, were ascribed by Cullen to debility, or weakened action of the Nervous System; and the re-action of the hot stage he considered to be caused by the Vital Force, which is indirectly raised by the operation of the cold stage. This theory of Fever, which in part belongs to Hoffman, Cullen supported with a mass of circumstantial evidence;

and though subsequent authors have loudly assailed it with hard names, yet it still remains unshaken; but there is a wide difference between censure and argument. As Cullen's work is in every one's hands, I shall enter into no detail of the facts on which his theory is established; but, supposing it to be true, that the cold stage of an Ague proceeds from diminution of the Vital Force, it is obvious, that by raising it effectually before the accession of the fit, all the symptoms of the cold stage should be arrested. It was from a deep impression of the truth of this conclusion that I recommended Dr. Sillar to apply externally the nitrate of silver in a case of Quartan Ague, which had lasted upwards of twelve months, and had resisted both bark and arsenic. The eschar was made an hour before the accession of the paroxysm; we returned to see the patient at the period when the cold stage usually ended, but it had not come on; our entrance roused him from a comfortable sleep. It would be superfluous to descant here on this synthetic proof of Cullen's theory; I leave it for the discussion of the contending theorists of the present day.

Bark is usually so far successful in the cure of Intermittents, that any proposal to supersede its administration, would most justly merit severe reprehension; but, now and then, it either fails,

or its operation is so tedious as to be unavailable. In such cases, if two or three paroxysms be prevented by the nitrate of silver, the bark is afterwards more efficacious. An eschar the size of a sixpence, on any part of the spine, will generally be sufficient to support the Animal Heat, and maintain the natural expansibility of the extreme vessels. The bark should be discontinued so long as the eschar prevents the paroxysms; but when they return, the bark must again be ordered.

Cholera of India.—As this disease has ravaged the greater part of Asia, and has now reached the frontiers of Turkey, it is not improbable that Europe may likewise come under its dreadful scourge. I shall, therefore, briefly state a few practical rules to direct those to whom this epidemic will appear a new disorder. Its course is so rapid, that it is not only necessary to make choice of those remedies that are best adapted to its cure, but to give cautions against those which might be pernicious. The administration of purgatives, not even excepting calomel, is followed by the most disastrous consequences. As well might the practitioner expect to stop a hemorrhagy by warm fomentation, as to cure the Cholera of India with purgatives. There are two indications of cure which should be steadily kept in view, namely, to arrest the discharge of serum from the intestinal exhalants, and to restore the

functions of the nervous system. An artificial re-action must be effected, or the patient will almost inevitably die. If the physician sees his patient about the beginning of the cold stage, a strong dose of ether must be ordered, with cold brandy and water. The intolerable thirst should be relieved by abundance of lemonade. The patient should be put to bed, and covered with four or five blankets, and sinapisms must then be applied to the feet and abdomen. This practice, when timely begun, will seldom fail to bring on a sufficient re-action to remove the disease.

If the second stage has continued a considerable time before the arrival of the medical attendant, and if there be present any symptoms of coma or delirium, more active practice is necessary; the patient must be freely bled, to relieve the brain from the unusual load of blood; and this object may, in some instances, be most effectually accomplished by opening the jugular vein. The lowness of the pulse must not deter from the use of the lancet; it, on the contrary, shows that bleeding is imperiously requisite. After the bleeding, the abdomen should be cauterized with nitric acid, diluted with an equal quantity of water. Mr. Powell applies the acid in this state till the skin becomes red, and then washes the part with a solution of the carbonate of potass. The neatest way of effecting an artificial

re-action, is by applying the nitrate of silver on the spine; but I recommend Mr. Powell's method, because it has been extensively practised. Blisters of cantharides are of no use; the fate of the patient is commonly decided long before they begin to operate. No time should be thrown away on the hot bath; it is sometimes injurious; the sudden application of heat to the body, when its vital action is very low, is not without pain and danger.

Hemiplegia.—In these kingdoms, the treatment of acute hemiplegia cannot be improved. Bleeding and blistering often remove this disease in the course of six weeks or two months; but if, at the end of this period, the use of the paralytic side be not partially restored, a cure is generally considered hopeless. If, however, all the apoplectic symptoms be entirely removed, and there remain no appearance of plethora of the cerebral blood-vessels, even chronic hemiplegia may sometimes be greatly benefited, by a succession of small lunar caustic eschars. It is impossible to say, *à priori*, in what case this treatment may be successful; but this information is very easily ascertained, by making an eschar over the course of the nerves of the paralytic arm, either in the axilla, or above the clavicle; and if either the sense or motion of the arm be improved, just expectation may be entertained of alleviating the disease.

The nervous system of those individuals who possess the sanguine temperament, is most easily excited by the nitrate of silver; a circumstance which is to be borne in mind, when this substance is applied to the spine. But when hemiplegia is relieved by lunar caustic, the cure goes on as fast when the eschar is about half the size of a sixpence, as when it is much larger; the nervous system requires a constant, but mild stimulant. The applications may be made on the back of the neck, and renewed every twelve or fourteen days. The longer a patient has been under the operation of the nitrate of silver, the more sensible he becomes to its influence; but if the treatment be pursued in a judicious manner, and only in proper cases, no untoward circumstance can arise from its use.

Neuralgia.—The eschars for the cure of neuralgia of the sacral extremities, may vary from the size of a shilling to that of half-a-crown. The caustic must be applied over the course of the affected nerve, and rubbed till the part assumes a red colour studded with grey spots. Rest and warmth are to be strictly enforced during the cure, and a considerable time after recovery.

White-swelling.—The custom of applying violent stimulants in this disease, and converting chronic into acute inflammation, being universally followed by the regular as well as empirical part

of the profession, I shall not venture to say more against it than I cannot possibly avoid. By producing a discharge or counter-irritation, I have never once succeeded in the cure of white-swelling, and seldom indeed have I seen others more fortunate.

The proximate cause of white-swelling, I conceive to be defective expansibility of the veins and absorbents; the wasting of the muscles of the diseased limb, is a certain proof that its nerves are not performing their functions. If, then, defective expansibility of the veins and absorbents, be the true pathology of white-swelling, it is obvious, that it must be far more consistent with the vascular mechanism, to raise their expansibility to a par with the arteries, than to incur the hazard of a painful and tedious active inflammation. Absorption is therefore the most scientific method of treating this dangerous malady; and I have no difficulty in saying that it is far more successful.

The cure of white-swelling should be commenced by the application of a dozen or two of leeches to the joint, unless the patient's general health be already too weak, to bear even local bleeding. Leeches are preferable to cupping, as they do less mechanical injury to the joint. Two days after the bleeding, a lunar caustic eschar, as large as half-a-crown, must be made at one

side of the patella, and the whole joint must be enveloped in a poultice, and maintained perseveringly in a state of rest. When the eschar comes away, the poultice may be discontinued, and the sore dressed with cerate or dry lint, and allowed to heal without delay. When the sore is quite skinned over, a fresh eschar may be made on the other side of the patella, and treated in every respect like the first. It is not amiss to keep a measure of the joint, to see the progress of the cure. For constitutional treatment, I generally employ alterative doses of calomel and James's powder; but I am not certain that much good is derived from these medicines. Small doses of rhubarb are sometimes beneficial. When sinuses exist, they must not be laid open, if the cure be attempted on the principle of absorption. The patient should not be allowed to walk about for some weeks after the swelling is gone, and cold must be carefully avoided. By this treatment, the patient suffers comparatively little, and the cure is almost certain, if the constitution be otherwise good, and the disease recent. The actual cautery, blisters, and potass eschars, frequently defeat the purpose of the practitioner, from the violence of their operation. As white-swelling occurs most commonly in scrofulous constitutions, it is consequently often combined with diseases of the other organs,

such as tabes mesenterica, tubercles of the lungs, rickets, and hydrocephalus; it is not, therefore, to be presumed, that by any local application, the scrofulous tendency of the animal economy can be eradicated.

Many facts which I already possess, as well as rigorous analogy, might induce me to recommend the external application of lunar caustic in some other obstinate diseases; but I am unwilling to promulgate any opinion, of the accuracy of which my own mind is not entirely satisfied; but I venture to assert, that it presents the physiological practitioner with curative means, for which the *res medica* offers no substitute. I should even here have enlarged more on its medical properties, were it not that my friend Dr. Sillar is now occupied on this subject, and will perhaps lay his observations before the public.

FINIS.

James Smith, Printer, Liverpool.